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Jun / Jul 09, Issue 131
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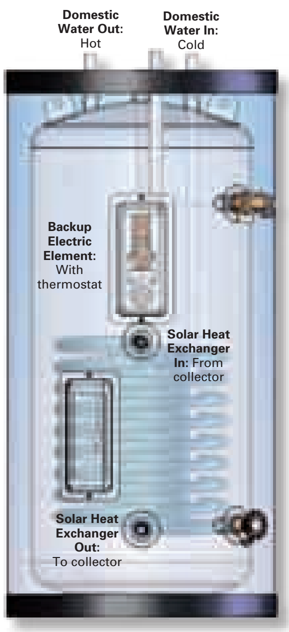
June & July 2009

Clockwise from bottom left, courtesy: Phillip Neal; www.solarwork.com; www.seventhgenergy.org; www.htproducts.com; Craig Allyn Rose; www.hondapowerequipment.com

On the Cover

Aspen Crouter and Jake Kollmar of Highland Energy Systems work on a Proven 6 kW turbine, 175 feet above the ground.

Photo by Arlene Smith



Regulars

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from us *to you*

Doing It **Yourself**

We've been receiving a stream of questions from *Home Power* readers about books encouraging do-it-yourselfers to build their own solar-electric modules—some promise a functional system for a few hundred bucks. For the record, *forget about it*. Building a solar-electric module is a great science project, but the reality of the project stops there.

This thread did get me thinking about where DIYers stand in today's renewable energy landscape. Over the past 20-plus years, we've seen hands-on readers design and install small systems that rival the workmanship of seasoned pros. We've also seen our share of owner-installed systems that fall under the "disaster" category.

Poor design work will cripple a solar-electric system's energy harvest over its entire lifetime—25 years or more—and undermine the return on your financial investment. While bad design impacts energy production, bad installations can result in damaged equipment, fires, property damage, injury, and death.

So before undertaking a hands-on solar-electric project, take some time to think about the following:

Consider the project. A small, low-voltage off-grid system is a completely different animal than a residential-scale grid-tied system, which can produce voltages as high as 600 VDC. Homeowners should not undertake the latter unless they have experience working with high-voltage electricity.

Assess your design knowledge. Blowing a system design can be as simple as one miscalculation or one poorly selected component. Doing your homework and seeking out design advice is the first step in building a system that will not only work, but work *well*.

Be realistic about your installation skills. Unless you have experience working with electricity, knowledge of the *National Electrical Code*, and the correct tools and protective equipment to perform the installation safely, hire a licensed solar-electric installer.

Determine your goals. If you're looking to save a few bucks by installing a system yourself, here's a reality check: Depending on where you live and the complexity of the system, installation costs for a residential system may range from 10% to 20% of the total system's cost. You'll need to weigh whether the savings are worth it, and determine if homeowner-installed systems qualify for rebates that may be available in your area.

Most do-it-yourselfers have one thing in common—they get excited about a project for the project's sake. They tackle it because they enjoy the learning experience and doing the work with their own hands. But experienced do-it-yourselfers have learned, sometimes the hard way, which projects are doable and which ones are not. This awareness is one of the most useful tools you can carry when you're considering a home-scale RE installation.

—Joe Schwartz for the *Home Power* crew

Think About It...

"If your project doesn't work, look for the part that you didn't think was important."

—Arthur Bloch, author of (you guessed it) the Murphy's Law *books*

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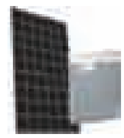

ASG Power Kyocera 1.6 kW GT Kit
Features a Fronius Inverter IG Plus 6.0-1 uni and Kyocera KD205GX-LP 205W 16V panels.
Our Price: $8,683.00

ASG Power 3.0kW GT Kit
Features an SMA SB 4000US, 4000W Inverter and Schüco 180-SPU-4 180W 16V panels.
Our Price: $15,276.00

ASG Power Kyocera 4.9 kW GT Kit
Features a Fronius Inverter IG Plus 6.0-1 uni and Kyocera KD205GX-LP, 205W panels.
Our Price: $24,183.00

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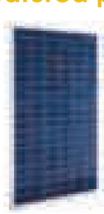


Evergreen Solar

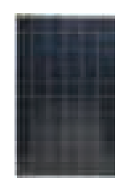
ES-A-205-f2ab**	**$666.00**	$3.25/watt
ES-A-200-f2ab**	**$642.00**	$3.21/watt

*Pallet pricing
**Blemished modules are only visualized blemished. The are fully warrantied, UL Listed, and generate normal rated power.

Kyocera

KD205GX-LP	**$695.00**	$3.39/watt
KD180GX-LP	**$610.00**	$3.39/watt
KC130TM	**$519.00**	$3.99/watt
KC85T	**$389.00**	$4.58/watt
KC50T	**$231.00**	$4.62/watt

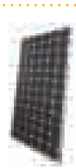
*Pallet pricing



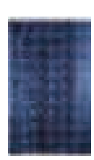
Sharp

ND-V230A1	**$1,012.00**	$4.40/watt
ND-224U1F	**$838.00**	$3.74/watt
ND-216U1F	**$862.00**	$3.99/watt
NT-175U1	**$676.00**	$4.06/watt

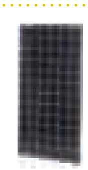
*Pallet pricing



Suntech Power
STP175S-24Ab-1 175W 24V Panel
Our Price: $637.00 $3.64/watt
*Pallet pricing



REC Solar
SCM220 220W 20V Panel
Our Price: $862.00 $3.92/watt
*Pallet pricing



Sanyo
HIP-210NKHA5, 210W 30V Panel
Our Price: $878.00 $4.18/watt
*Pallet pricing

featured products

Enphase Micro-Inverter
M190-24-240-S01
Our Price : $ 192.00

Outback Flexmax 80
Charge Controller
Our Price : $ 580.00

Morningstar Sunsaver
SS-MPPT-15L Charge Controller
Our Price : $239.00

Southwest Windpower
Air-X Land 12V Wind Turbine
Our Price : $699.00

SMA SB 7000US
7000W inverter
Our Price : $4,108.00

Xantrex XW6048-120/240-60
Hybrid Inverter Charger
Our Price : $ 3,656.00

Batteries

	VOLTS/Ah	OUR PRICE
Deka/MK Battery 8D G LTP Gel Cell	12V 225Ah	**$557.00**
Surrette S-530 Deep Cycle Battery	6V 400Ah	**$372.00**
Concorde Battery PVX-2580L	12V 255Ah	**$862.00**
Trojan Battery T105	6V 225Ah	**$160.00**

Charge controllers

	AMPS	OUR PRICE
Xantrex XW Solar Charge Controller	-	**$557.00**
Xantrex C35 Charge Controller	35A	**$104.00**
Apollo T80 Charge Controller	80A	**$657.00**
Blue Sky Energy Solar Boost 6024HDL w/Display	60A	**$583.00**
Morningstar TriStar TS-60 Charge Controller	60A	**$202.00**

*Please note pricing and availability subject to change in this crazy market

Solar Savings by the Numbers

Rather than paying more money to buy the same items separately at our local supermarkets, my friends and I often buy in bulk from wholesale warehouse clubs—we share the membership fee, we share the cost, and we all share the savings. It's our very own bulk-buying cooperative.

That's essentially the idea behind One Block Off the Grid (1BOG), a San Francisco-based organization promoting solar energy through old-fashioned community organizing and group discounts.

By banding people together in different cities, negotiating on their behalf, and buying in bulk, 1BOG is helping homeowners get discounts on solar-electric systems—up to 20%. The goal is to increase the adoption rate of solar energy by taking the fear out of the buying process.

By banding people together in different cities, negotiating on their behalf, and buying in bulk, 1BOG is helping homeowners get discounts on solar-electric systems—up to 20%.

Courtesy www.1bog.org

"For someone who is unfamiliar with the technology, the buying process can be daunting," says Dave Lorens, general manager and cofounder of 1BOG. "It's difficult to know which installer to trust and whether prices are fair. We try to fix these problems and eliminate the trust barrier."

The startup is the brainchild of Dan Barahona and Sylvia Ventura. In 2007, the couple began exploring the idea of a solar-electric system for their San Francisco home. Even with backgrounds in electrical engineering and biotechnology, the couple found the buying process to be overly complicated by jargon, technical concepts, and government regulations.

They took matters into their own hands, researching the ins and outs of solar over several months. In the end, they installed a 2.5 kW PV system on their home and found the inspiration to create 1BOG.

The couple partnered with Lorens, then a salesperson who worked for their installer, and shared their ideas for streamlining the buying process. Working from a coffee shop, the trio hatched the concept for the 1BOG initiative. (See "Behind 1BOG" sidebar.)

In May 2008, 1BOG ran its pilot campaign in San Francisco, with a small team of staffers and volunteers going door to door, stopping people on the streets, sending out e-mails, and attending renewable energy fairs to generate interest in their "group purchase" concept.

Their grassroots efforts proved fruitful: 180 homeowners signed up; 80 followed through with professional site surveys arranged by 1BOG; and of those, 42 installed PV systems on their homes—all at a discount of 20%, thanks to 1BOG's bulk-buying muscle.

Behind 1BOG

1BOG capitalizes on the fact that there is power in numbers. Signup is free, and once 100 homeowners in a city or town are on board, 1BOG begins the proposal process and acts as a representative for the homeowners—negotiating with and selecting installers. Homeowners schedule evaluations with the installers and decide whether to follow through with an installation. There is no obligation to buy. 1BOG generates revenue through a referral fee from each selected vendor participating in 1BOG programs—roughly 25 cents per installed watt, while installers save money on sales and marketing costs.

"Growing the interest virally is a key component to removing marketing costs to the installer so we can pass those savings on to the consumer," says Lorens. "The rest of the savings come from the negotiations and economies of scale involved."

Start a solar-electric campaign in your city by signing up at www.1bog.org. All it takes is 100 signups to launch a program.

The company's initial success paved the way for 1BOG's first full-scale effort earlier this year—also in San Francisco, with a goal of signing up 800 Bay Area residents. Key to the 1BOG formula is social networking. Those who sign up for a campaign are encouraged to reach out to neighbors, friends, and colleagues to grow the network even more.

Now backed by the resources of its new parent company—Virgance, an activism startup firm that uses social networking to support grassroots activism, 1BOG seems to have what it takes to launch buying clubs nationwide. So far, the company has launched in 20 cities, and has strong member bases in California, Colorado, Louisiana, and Oregon.

—Kelly Davidson

Bright Lights, Big City, Big Solar

Atlantic City—New Jersey's neon-laden, gambling mecca—is home to the largest single roof-mounted PV array in the United States. The Atlantic City Convention Center and Visitors Authority (ACCVA) is now home to a 2.37-megawatt solar-electric system, which was completed in December 2008 and commemorated in a ceremony this spring.

The system—which covers approximately 290,000 square feet of the roof—is comprised of 13,486 monocrystalline PV modules capable of producing 26% of the convention center's annual electrical consumption. American Capital Energy of Massachusetts managed the project integration and installation as general contractor for ACCVA.

The system was made possible by a power purchase agreement with Pepco Energy Services of Arlington, Virginia. Pepco owns and operates the equipment and sells the power generated by the system to the convention center, which, as a public entity, does not qualify for federal or state tax credits. As a private company, Pepco does.

Over the 20 years of the contract, officials estimate that the system will save $4.4 million in energy costs. Annually, the system is projected to offset 2,349 tons of carbon dioxide.

New Jersey was named among *Home Power's* Best Solar States in 2008 (see *HP124*).

Energy-Sipping Converter Boxes for Digital TV

After midnight on June 12, you can say sayonara to all analog television stations, as they'll be switched off across the nation. If your TV receives its signal over the air with an antenna or "bunny ears" and does not have a digital tuner, you'll be in the dark, lamenting your once-favorite shows—unless you pony up and purchase a digital converter box. But before you buy, make sure you specify an energy-efficient model: An Energy Star-rated digital-to-analog converter box is the ideal way to keep your favorite channels—without wasting energy.

According to the U.S. Commerce Department, which manages the government's digital TV coupon program, the Zenith DTT901 converter box consumes less energy in "on" mode than any other converter eligible for the $40 federal government discount coupons. The Zenith DTT901 also performs better than the guidelines of the Energy Star program.

Converter boxes that qualify for the Energy Star logo must consume no more than 8 watts in "on" mode and no more than 1 watt in "sleep" mode. The Zenith DTT901 significantly outperforms in both categories. Official energy measurements for the DTT901 are 3.9 watts when on and 0.6 watts in sleep. To further conserve electricity, the DTT901 also turns off automatically after four hours of inactivity.

The converter box is available at national retailers at a suggested retail price of less than $60—just $20 with the government coupon.

The Zenith DTT901 converter box consumes less energy when "on" than any other converter.

Courtesy www.zenith.com

Sanyo HIT Power N Series PV

This spring, electronics and solar module manufacturer Sanyo (www.sanyo.com/solar) introduced its Hit Power N series PV modules. Like their predecessor B series, the N series is comprised of hybrid PV cells, each having a thin amorphous silicon layer that surrounds a single crystalline silicon cell. This technology allows this module line to achieve up to a 17.1% conversion efficiency. (Note: Unlike the Sanyo HIT Double, the N series is not a bifacial module.)

The N Series ranges from 205 to 215 watts and has 72, 5-inch cell configuration as compared to the 180 to 205 watt, 96, 4-inch cell B series. Fewer cells means lower module voltage, which allows for using more modules in series, and also makes the modules easier to use in battery-based systems. This coupled with the higher power output per module (due to the larger-diameter cells) can reduce the number of parallel strings required for a desired array output. Having fewer module strings in parallel can reduce and/or eliminate the required number of series fuses and combiner boxes (or combiner box capacity) to reduce installation costs.

—Justine Sanchez

Sanyo's new HIT Power N series PV modules achieve up to a 17.1% conversion efficiency.

Courtesy www.amtecsolar.com

AMtec Solar Releases New Combiner Box

Early this year, Hayward, California-based **AMtec Solar** (www.amtecsolar.com) released a new combiner box, the Prominence 6R, built for the light commercial and residential PV market. This model can accommodate up to six input circuits. The combiner box is rated up to 600 VDC and houses "finger-safe" fuse holders, listed to accommodate fuses rated up to 15 amp each. It has a standard black or grey NEMA 4 outdoor-rated powder-coated steel enclosure, but NEMA 4X options in fiberglass and stainless steel are also available. Helpful installation features include torque values and wire ranges that are silk-screened on the custom backpan.

A Smarter Power Strip Helps Mind Your Electricity Use

P3 International's (www.p3international.com) new Kill A Watt PS is the most recent addition to the company's line of electricity-usage monitors. A power strip with the electricity usage monitor built in, this device can measure multiple electric loads simultaneously while they're working. The Kill A Watt PS keeps tabs on the voltage, current, active power, power factor, kilowatt-hours, and leakage current from each individual appliance plugged into the strip. It also offers protection from abnormal voltage, overcurrent, overload, and surge to the provided eight outlets. Maximum output current is 15 amps, but it has a programmable breaker current that can be adjusted to 2, 5, 10, or 15 amps.

—Justine Sanchez

Courtesy www.p3international.com

Kilowatt Ours: A Plan to Re-Energize America

This award-winning documentary from environmentalist Jeff Barrie begins by asking two questions: “What if, every time we flipped a light switch at home, a mountain exploded in West Virginia? Or every time we turned on the air conditioner in summer, a child suffered an asthma attack?”

The film goes on, not to whine about the dire environmental situation we’re in, but rather to use compelling footage to portray how our energy appetites and fossil-fuel demands affect our environment, health, and culture. Dramatic scenes of mountaintop-removal mining for coal, and air pollution due largely to coal-fired power plants, are enough to make even the most dispassionate of individuals think twice about their energy choices.

Barrie confronts the dangers of coal-generated electricity with a good balance of facts and whimsy. Furthermore, he presents practical ways in which ordinary citizens can address the energy and environmental challenges the film presents. In addition to talking about home renewable energy systems, the film promotes the idea of buying green power.

And his priorities are in the proper order. Barrie does not jump to renewable energy as the solution before spending much of the film talking about the importance of energy efficiency and conservation measures, with specific advice and demonstration. He shows how simple changes can have dramatic results in a country where coal is used to make 52% of our electrical energy.

A DVD of the film is available with a $25 donation to the Kilowatt Ours project, Barrie’s Tennessee-based nonprofit movement that promotes energy conservation through outreach programs in schools and communities. Complete with three versions of the film—the full 56-minute documentary, as well as 24- and 12-minute versions, the DVD makes a useful educational tool and a worthy addition to any personal RE collection. For full details, go to www.kilowattours.org.

—Ian Woofenden

Honoring the Earth

Courtesy www.solarenergy.org

Faced with the dark legacy of uranium mining and the prospect of nuclear waste sites encroaching on their land, more and more Native American tribes are looking at renewable energy sources to power their communities and create new jobs. But realizing RE goals is no easy task for indigenous communities in the United States—many of which cope with unemployment, high mortality rates, social ills, and poverty levels that rival those in the poorest developing countries.

No stranger to working in Third World conditions and delivering projects with little or no budgets, Solar Energy International (SEI) is lending a much-needed helping hand to the Native American community. The Colorado-based organization—a provider of RE education and installer training—has teamed up with Native American groups to help coordinate RE projects and training workshops for native communities.

Over the years, the SEI staff has contributed its expertise and labor to several projects—ranging from residential PV installations to sustainable housing initiatives. For its latest efforts, SEI partnered with Honor the Earth (HTE), a Minnesota-based nonprofit group that secures grant funding for renewable energy projects on native lands.

> "Native communities are often faced with the false choice of either developing energy sources or protecting ecosystems. Solar power, like other renewables, represents an opportunity to not have to choose one or the other."

"Native communities are often faced with the false choice of either developing energy resources or protecting ecosystems. Solar power, like other renewables, represents an opportunity to not have to choose one or the other," says Winona LaDuke, executive director of HTE.

For its role, HTE organizes the projects within a community, easing any political and social concerns that may arise. Once the community greenlights the project, SEI's crew gets involved, managing the system design and installation. SEI also works its industry connections to secure donations and discounts from equipment manufacturers, which are critical to the projects' budgets and overall success.

SEI's most lasting contribution, however, comes from the training it provides. Through on-site workshops and demonstrations, SEI empowers tribal members with the skills to become trainers and leaders in renewable energy. To maximize the project's reach, members from other tribes and reservations are invited to participate as well.

But the impact goes beyond the building of RE economies on native lands, says Matt Harris, SEI's program coordinator.

"Renewable energy can bring food, fuel, and economic security to back to tribal lands," says Matt, "but even larger than that, RE can revitalize cultural traditions and beliefs that are fading away. It can help younger generations reconnect with the elder wisdom, and help them once again come to respect and revere the sun, the water, the animal spirits, and the natural world as their elders do."

Through its alliance with HTE, as well as the Intertribal Council on Utility Policy (a nonprofit council of federally recognized Indian tribes in North and South Dakota, Nebraska, and Iowa), and other Native American organizations, SEI has developed projects for several tribes, including the Navajo, Hopi, Lakota, Yurok, Zuni, Anishinabe, and Western Shoshone.

Most recently, SEI and HTE worked together to install a solar-electric system on the Skull Valley Goshute Reservation in Utah. The system, which was installed on one of the reservation's five homes, was given to the Goshute tribal members for their successful efforts in defeating a proposal for a nuclear waste storage facility on their reservation.

"We hope that the success of this installation will lead to the increased use of renewable energy on our reservation and others," says Margene Bullcreek, the Goshute member who led the anti-nuke effort from her home office, now powered by a ground-mounted PV system.

—Kelly Davidson

SEI's collaboration with Honor the Earth has resulted in three PV installations thus far, and more are planned for the future. To learn more or lend a helping hand, log on to www.solarenergy.org.

the circuit
SOLUTIONS

PV Systems Aid in Mining Mitigation Efforts

Courtesy Lena Wilensky

PROJECT: Standard Mine cleanup site

SYSTEM TYPE: Off-grid PV

INSTALLER: Nunatak Alternative Energy Solutions

DATE COMMISSIONED: October 2007

LOCATION: Crested Butte, Colorado; 38.8°N latitude

AVERAGE DAILY SOLAR RESOURCE: 5.56 peak sun-hours

ARRAY CAPACITY: 220 W STC

ESTIMATED ANNUAL PRODUCTION: 645 Wh (November: lowest peak sun-hours); 1,005 Wh (June: highest peak sun-hours)

MODULES: Two Mitsubishi MF110EC4, 110 W STC each

CONTROLLERS: Prostar 30 with meter; Tristar 45 (as PV diversion controller)

BATTERIES: Two MK8A31 12 V AGM, 105 Ah at the 20-hour rate

ARRAY INSTALLATION: Side-of-pole mount

Many old Colorado mine sites have acid drainage issues that could plague the environment forever—unless remediation measures are taken. Thankfully, innovative solutions are being tested to address these problems.

Compared to the conventional energy-intensive and expensive water treatment plants usually used to treat mine effluent, new PV-powered bioreactors hold the promise of being one of the long-sought-after solutions for the numerous abandoned mine sites that plague the mountain landscape. In these systems, mine effluent is routed into a large pit filled with horse manure and wood chips. Microorganisms in this mixture scavenge the heavy metals from the contaminated water through their own metabolism. The acidic water filters through the bioreactor, is transferred to a series of wetlands and, finally, is filtered through a large tank of crushed crab shells to help raise its pH. After all of these treatments, the water is virtually contaminant-free.

However, bioreactors of this type had never been tested in an extreme climate, and the U.S. Environmental Protection Agency wanted to first collect data on a small one before building on a bigger scale. An abandoned mine site outside of Crested Butte that was polluting the local watershed with acidic, heavy-metal-laden water was the perfect place to start.

But powering pumps and data monitoring equipment in a remote mountain valley at 10,000 feet is no easy task, especially when winter access is only via skis and snowmobiles—when avalanche conditions allow. Since PV modules love the cold and require very little maintenance, they were the obvious solution. In fact, the EPA had already ordered "PV power packages" for their equipment before they contracted with Nunatak Alternative Energy Solutions to help with the installation. Three separate off-grid PV systems are installed at the site, with a fourth one downstream, to power various pumps and data loggers.

Powering pumps and data monitoring equipment in a remote mountain valley at 10,000 feet is no easy task, especially when winter access is only via skis and snowmobiles—when avalanche conditions allow.

One of the main concerns was how to keep water samples from freezing over the winter months, given that temperatures can drop to a frigid -40°F. Although the equipment shed was heavily insulated, there was no way to replace lost heat. Since one of the PV arrays was greatly oversized to prevent any lapses in power, we decided to use a PV diversion controller with a heater as the dump load. Concerns about starting forest fires ruled out using any kind of open-air resistive heater, so a simple DC water heating element immersed in a fluid-filled 20-gallon metal drum was used. To prevent the fluid from freezing in the event of a system failure, the drum was filled with a 50/50 propylene glycol and water solution. The drum was set into a larger container and the voids around it filled with sand, providing extra mass for heat storage.

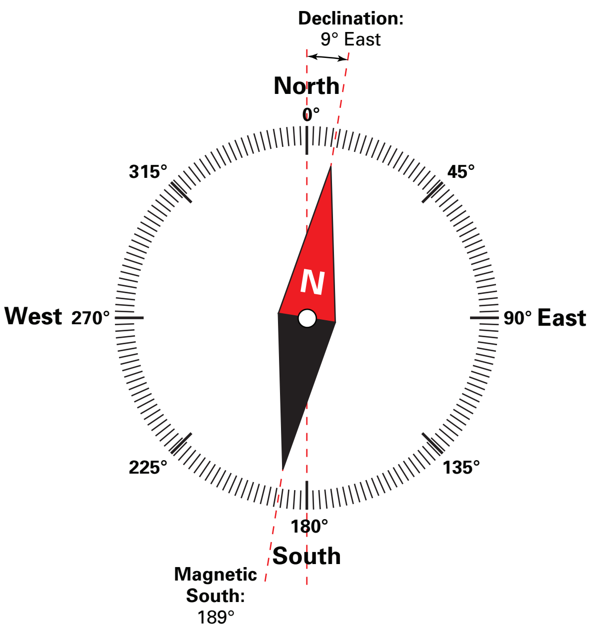
The PV system first charges the batteries, which supply power to the data equipment and pumps. When the batteries are fully charged, PV power is routed to the heating element. A second charge controller serves as a low-voltage disconnect.

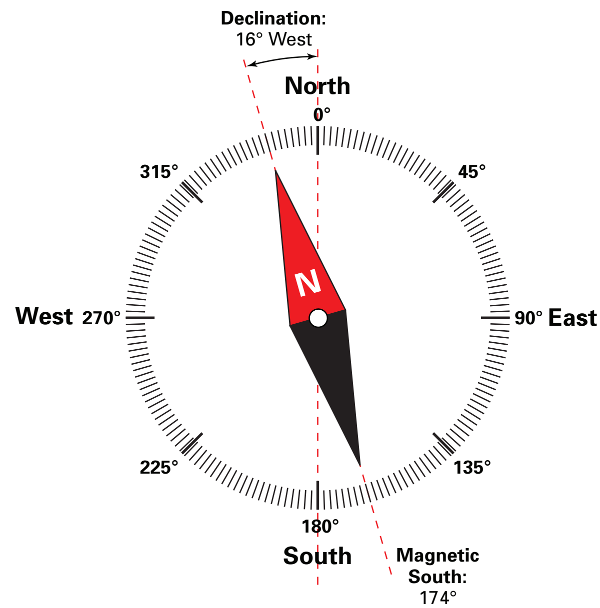
Even after a winter of record-breaking snowfall, the system has been working well, with the shed temperature never falling below freezing, and no recorded temperatures lower than 60°F in the heat-dump tank. Even with one of the PV modules buried in the snow for several weeks, the system managed to stay running, keeping the shed relatively warm and the microbial activity continuing to clean the contaminated water.

—Lena Wilensky

Finding True South

When you're siting your PV system or your passive solar house, accounting for magnetic declination can help optimize performance.





In the Northern Hemisphere, stationary PV arrays and the long side of passive-solar designed homes are oriented south to maximize solar gain. But using your compass to find south will only give you an indication of magnetic south—not true south. In the Northern Hemisphere, a compass needle aligns itself along the magnetic north-south line. In most cases, solar thermal and PV systems should be oriented to "true" or "solar" south ("geographic" south), so you'll need to account for magnetic declination—the angular difference between true and magnetic north.

The main cause for this discrepancy is the Earth's nonuniform, conductive, fluid outer core that consists mainly of iron and nickel. This layer pulls your compass needle away from true north/south. Depending upon your location on the planet, the "pull" varies in strength and direction.

The magnetic declination is an east or west correction that is either subtracted or added to your magnetic south compass reading. If you know your latitude and longitude, or your zip code, you can find the magnetic declination for your site at the National Geophysical Data Center's Web site: www.ngdc.noaa.gov/geomagmodels/Declination.jsp.

Let's say our PV system is in an area near Santa Fe, New Mexico. We find that the magnetic declination for this region is listed as 9°, 15′ east. (To make things easier, round this value to the nearest whole degree value, which in this case is 9° east. Because there are 60 minutes per degree, if the minute value is above 30, then we would round up. But since our minute value is less than 30, we round down.) This means that true south is 9° east of magnetic south. If our compass needle is aligned so that north points to 0°/360° on the compass and the south points to 180°, then true south will be at 171° (180° – 9°).

Portland, Maine, has a declination of 15°, 57′ west (which can be rounded up to 16° west). Here, true south is 16° west of magnetic south, or indicated by the 196° compass bearing (180° + 16°).

Depending on what resource you use to find magnetic declination values, they may or may not give the direction east or west, but provide either positive or negative values. Positive values have eastern declinations and negative values have western declinations. For example, if your area's declination is listed as -12°, then you know that your magnetic declination is 12° west. Conversely, if your locale's declination is 12°, then you know your magnetic declination is 12° east.

—Justine Sanchez

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Courtesy Josh Guikema

BIODIESEL IN CAMBODIA

Thank you for publishing *Home Power*. It has inspired me to get involved with renewable energy projects in Northern California and around the world. Last year, I spent seven months working on a *Jatropha*-to-biodiesel project in a remote village near Angkor Wat, Cambodia.

Despite a rapidly growing population and an increase in foreign investment, Cambodia is still a poor country with a very undeveloped infrastructure. The typical village family relies on a single 12-volt battery to power their home. Usually, one person in a village has a generator station where everyone will go to recharge or exchange their batteries. With the price of PV and other technology out of reach, my mission was to supply a village with *Jatropha* seeds and the knowledge to grow the fuel stock to make homegrown biodiesel for their generators.

Jatropha is a perennial shrub native to subtropical regions, notable for its high-oil-yielding seeds and ability to grow in regions prone to severe drought. It has been gaining much attention in Southeast Asia for its potential as a cash crop. It grows fast in full tropical sun, up to 5 meters tall with a tough stem, thick succulent leaves, and lime-sized fruit containing five oil-rich seeds. One hectare of *Jatropha* can yield more than 1 ton of seeds per year, or more than 1,500 liters of oil, depending on rainfall.

With my background as a greenhouse manager, I helped villagers and students develop a *Jatropha* nursery and plantation. We planted many hectares and built a structure to house an oil press and biodiesel refinery, along with a generator to refresh the community's power supply and power the Children's Hospital's backup generators. It was a great adventure to see this project through, from germination to power generation. Our project created a plantation of trees that will perpetually bear green, renewable energy for the farmers and villagers that care for them.

As an unofficial diplomat, my real success was helping these people to understand and embrace a source of renewable energy that can empower their lives. With a new forward-looking U.S. administration facing economic, energy, and climate crises, renewable energy is the hope and solution for all these problems. Thank you for your revolutionary magazine.

Josh Guikema • via e-mail

Courtesy www.conergy.us

Conergy's Quickstones can be inserted into the rail anywhere along its length.

PITCHED-ROOF MOUNTING METHODS & SPECIFICS

Rebekah Hren's article "Pitched Roof Mounting" (*HP130*) was informative and well crafted. In the interest of clarity for *Home Power* readers, I would like to point out an important omission and correction. First, the correction: When describing Conergy's Quickstone nuts, Hren notes that they can be "slid down the channel and into position." The unique aspect of Conergy's Quickstones is that they do not have to be slid down the channel like oval head-bolts or T-bolts. Rather, the Quickstone can be inserted into the rail anywhere along its length—and with two or three turns of the bolt, the Quickstone will remain in the channel but can be slid to its precise final position and then tightened securely. This capability significantly reduces installation time and cost for Quickstone users.

An important point of clarification in the "Beyond Comp Shingle" section is that Conergy offers installers several unique mounting options for tile roofs that do not require drilling through the tile. In some cases, the tile need not be altered at all. Conergy's tile roof hooks are available for flat tile, barrel tile, and slate roofs and have proven quite popular with installers in the Southwest, where a significant percentage of residential rooftops are made of tile.

Don Massa, Product Manager, Mounting Systems •
Conergy Sales and Services, Americas

AN ACT OF THE PEOPLE?

I have a few comments to make about "It Takes an Act of Congress" in *HP130*. While I must applaud Michael Welch on a devotion to cleaning up the environment, I think that his column could have been improved on a few points.

First, Mitch McConnell is from Kentucky and Robert Byrd is from West Virginia (not vice versa). Not a big deal, but when you see a simple mistake like that, you start questioning the rest of the article. The second issue is his rant about the stimulus package, which is somewhat misleading. Michael chastised the House Republicans for voting against the stimulus bill despite "overwhelming public support." Excuse me? Thinking I missed something, I did a little research. I found two Rasmussen polls: one, conducted January 21, showed 45% support; another (February 4) showed 37% support. The CBS and Gallup polls from February 5 showed somewhat more support at 51%, but I would hardly call that "overwhelming."

While I would hope that all Americans care about a clean environment, there is a major difference between activism and politics. While an activist can be passionate about a single issue, a politician does not have that luxury. There are many issues that are interrelated. And do not forget that members of the House represent the people of their state. The people of California, for example, probably have a different set of priorities than, say, the people of Kentucky. If you represent the people of a coal-producing state, it may be hard to vote for a bill that may bring increased unemployment to your state. And let's face it, for many people, putting food on the table is their first concern, and everything else is secondary.

I do not write this because I want to defend the coal industry, since they have worked pretty hard to put profits before people and the environment. Nor do I wish to defend politicians. I am an independent because I am equally disgusted with the abuses of power by both the Republicans and Democrats. I just ask that people keep things in perspective.

AJ Reissig • via e-mail

Thanks for your comments, AJ. It is true that politicians need to be multi-issue, but it sure is a travesty to see how much sway corporate contributions and bevies of influential corporate lobbyists have over our legislators and in shaping our nation's energy issues.

Michael Welch • Home Power

EMF DANGER

I've subscribed to *Home Power* since around issue 40. I have attended two energy fairs in Wisconsin, and one here in Arizona. Finally, I live in an off-grid house! But it did not come about as I originally had thought. I moved off grid for health reasons. And those reasons are actively being brushed under the rug by powerful industry interests. The green movement much prefers to ignore us.

There are about a thousand of us here in Arizona and New Mexico who have had to head for the hills to get away from pollution—air pollution and electromagnetic pollution from transmission towers, etc.

So why do I write you about this? Because the solar revolution has a dangerous flaw. The inverters are a health problem in long-term use, unless they are designed to radiate much less.

Research is needed to prove this, of course. Much has been done on cell phone radiation to show its health effects. But it is too inconvenient a truth, so it is largely ignored. And "cigarette science" abounds. To get an overview by independent researchers, look at the BioInitiative Report (www.bioinitiative.org). You can also see resolutions by doctors and researchers in the field, by doing a Web search for "Frieburger Appeal" and for "Venice Resolution."

There is no question that we need to go solar, but we should do it wisely. But not by putting PV modules and inverters in school buildings. They belong in large central plants, not on rooftops, at least until inverters are designed to radiate less dirty energy. But, like industry not being willing to listen about global warming, so is the solar industry (and green activists) not willing to hear this. Please take this problem seriously. I am not a crazy person, just one with an unpopular message.

Steen Hviid • Snowflake, Arizona

ERRATA

The graph in the Steca freezer review (HP130) *was incorrectly labeled. The title "Monthly Energy Use…" should have been "Daily Energy Use…" The "Energy (kWh)" label on the left axis should have read "Energy (Wh)." And the "Avg. kWh/Day" label should have read "Avg. Wh/Day," since the numbers show average watt-hours (not kilowatt-hours) per day. The text correctly noted that our test showed overall average usage of only 120 watt-hours per day for this unit. We regret the error.*

Page 48 of "Solar Site Assessment" (HP130) *incorrectly states that "all three tools [the Solar Pathfinder, the ASSET, and the SunEye] include bubble levels and compasses as they must be leveled and aligned to true south." There are slight differences as to how each device is aligned. If the Solar Pathfinder is used manually, the sun-chart needs to be aligned to true south. If you're using the Solar Pathfinder Assistant software, then the chart needs to be aligned to magnetic south. The ASSET tool should be aligned to true south, and the SunEye should be aligned to magnetic south.*

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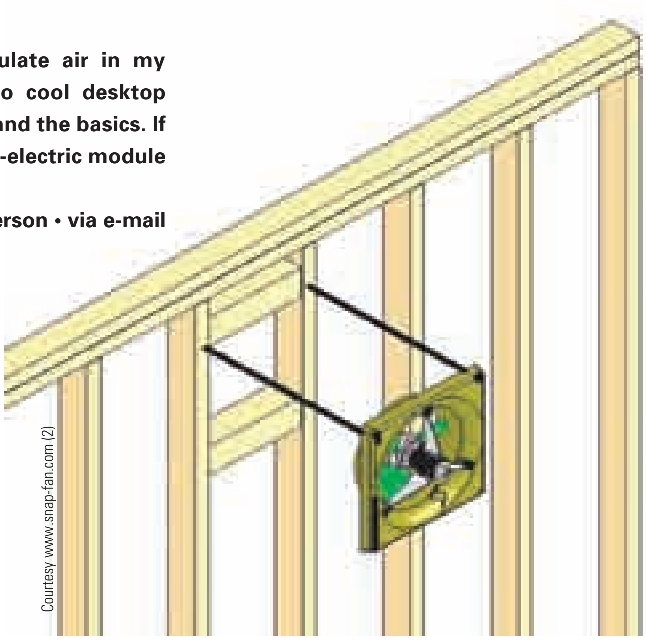
PV-Powered Fans

I'd like to use DC fans powered by photovoltaic modules to circulate air in my greenhouse. I favor the high-volume axial fans, like those used to cool desktop computers. I realize that these are too small, but I'm trying to understand the basics. If I know the motor's volt and amp specs, how do I determine what solar-electric module to buy? Take me to school, please.

Norman Anderson • via e-mail



Courtesy www.snap-fan.com (2)

PV-powered fans have been used successfully to exhaust greenhouses and sunrooms since the 1980s. They are quite appropriate because they vary in speed with the intensity of the sun, moving the most air when there is the most need to remove heat. Solar attic fans are commercially available and also may be applicable to this situation. Some manufacturers, like Solar National Air Propulsion (www.snap-fan.com), make solar fans that are suitable for wall installation

Electrically, a solar fan consists of nothing more than a PV module, a fan with a DC motor, sometimes an on/off switch (usually a thermostat), and some wire. There is no need for a current booster, other electronics, or batteries to help it start, because there is no load at startup except slight friction.

Greenhouse designers choose fans based on their air-moving capacity, rated in cubic feet per minute (cfm) relative to the loads, and the space's size and the solar gain. To make an informed decision, you should estimate your cfm requirements—you may be able to find guidelines from a greenhouse supplier. Of course, you can use more than one fan or larger sizes to add capacity. Try one perhaps, and add more if you need to.

For low-cost DIY project, you can try a salvaged or surplus fan or blower. A fan is usually best (blowers are optimum where more pressure is required). I suggest you only use a conventional brush-type motor, rather than a high-tech brushless motor (like a computer fan). Brushless types use electronic inverter circuits that may not handle the wide voltage range of a nonbattery PV source. These may not work in diffuse sun, and may fail in bright sun when the voltage climbs to 17 V or more. The old brush-type motors are more forgiving. If the motor has a long cylindrical shape, it is usually brush-type. Short the two wires together and spin it by hand. If shorting makes it harder to turn, it's brush-type. Although motor brushes eventually wear out, I've seen them last as long as 10 years.

It's simple to select a PV module for a fan. Determine the current that the fan will require. You may need to measure it yourself, using a 12 V battery and a multimeter capable of 10 A. A 12 V PV module will apply voltage of at least 16 V. That causes the fan to draw about 20% more current than it draws at 12 V. To start and run the fan early and late in the day, the PV module needs to be rated for yet another 20%. If you get a module rated for at least 50% greater current than the 12 V draw of the fan, it will work well. Consult a low-voltage wire size chart to determine the minimum wire size required.

You will probably want a thermostat in the system (unless there is already one built-in to a ready-made solar fan). It will prevent the fan from coming on when the sun is bright, but the greenhouse is cold. I have had good results with a "line-voltage thermostat," designed to switch 120 VAC at several amps. It has no trouble handling a few amps of DC current at low voltage. It can be mounted on the wall or elsewhere in the greenhouse. These thermostats are typically available from electrical or heating and air-conditioning suppliers. Ask for Grainger 2E158 or similar.

For a small greenhouse or sunspace of 300 square feet (floor area), your material cost may be about $500—or much less if you are resourceful.

Windy Dankoff, founder (retired),
Dankoff Solar Products (now Conergy, Inc.) •
Sante Fe, New Mexico

"Greenhouse designers choose fans based on their air-moving capacity, rated in cubic feet per minute (cfm)."

Predicting Solar-Electric Output

Courtesy Stacey Raymond

I have a six-collector (240-square-foot) flat-plate solar hot water system that nets about 1.5 million Btu per month (pictured at right). I have taken rough daily temperature-gain measurements for almost two years (twice a day) and am now even more convinced that solar energy does work well with the right design.

But how can I figure real-world net *solar-electric* production? Here's what I'm thinking: I would take the total wattage of the array (in my case, 4,100 W) and multiply that times the peak sun-hours (4.6) for Portland, Maine, to get a grand total of 18,860 watt-hours. I would then multiply that by 0.8 for losses and end up with 15,088 Wh, which is 15 kWh of solar-electric happiness per day.

Here's my conundrum: Do the 4.6 average daily peak sun-hours take into account the rainy days, or is this really just a sunny-day production number? And what factor should be applied to best estimate losses?

Stacey Raymond • Arundel, Maine

Peak sun-hours is a measure of solar energy available in a geographical area. It takes into account the real-world available sunshine, so you do not need to make any accommodations for cloudy days or wintertime. What the peak sun-hour value doesn't take into account is shading at your specific site. So if there's shade, you need to factor in decreased solar insolation due to local trees, buildings, and other obstructions. Your prediction should also factor in any deviation from optimum tilt angle.

One way to estimate system output for a batteryless grid-tied system is to use the National Renewable Energy Laboratory's PVWatts online calculator. Here, you can click on your location and enter your proposed array size, orientation, and tilt angle. PVWatts can be used for fixed or tracked arrays (www.nrel.gov/rredc/pvwatts/).

If you want to calculate a production estimate by hand, your 0.8 factor for losses will not be sufficient. Along with "losses"—such as those due to array soiling, wiring size and length, charge controllers (if included), breakers, and inverters—a derate factor should also adjust for a rating system that is not very accurate.

PV modules are rated in ideal conditions—at 25°C (77°F), an unrealistically low temperature for PV cells that are dark in color and sit in the sunshine all day. Few arrays experience those conditions very often, and one consistent characteristic of crystalline PV modules is that voltage decreases as temperature rises. Since instantaneous power is directly dependent on voltage, higher module temperatures mean lower output. PV system designers typically use a 0.7 derate factor for batteryless systems, and a 0.6 to 0.65 factor for battery-based systems.

In your example, take the 4.1 kW rated PV array times the 4.6 peak sun-hours and multiply by 0.70 for a batteryless system. This would result in a predicted production of about 13 kWh per day, or about 400 kWh per month. I say "about" because sun conditions vary from year to year, and different systems have different efficiencies. This sort of rough calculation is good enough for general predictions. Your kWh meter will tell the truth on a day-to-day and year-to-year basis.

Ian Woofenden • *Home Power* Senior Editor

"PV system designers typically use a 0.7 derate factor for batteryless systems, and a 0.6 to 0.65 factor for battery-based systems."

Hydro Pipe Expansion

I've heard that planning for pipe expansion and contraction is important for long hydro penstocks. How long does the pipe need to be before this is a consideration? What are the best approaches for dealing with pipe expansion and contraction to avoid joint blowouts?

John Hibner • Denton, Texas

With any length of pipeline, expansion from heat and contraction from cold is cause for concern. For instance, PVC pipe will lengthen about $^{1}/_{3}$ of an inch per 100 feet per 10°F, so a 250-foot-long PVC pipeline would lengthen about 4 $^{1}/_{2}$ inches with a temperature change from 40°F to 90°F.

Temperature changes are much less with buried pipeline compared to aboveground pipeline. But most designs necessitate some length of aboveground pipeline, such as stream crossings on bridges, trestles across low areas, entrances to the powerhouse, and exits from the intake structure. If expansion and contraction are not factored in to the design, the pipeline may experience joint

Courtesy Lee Tavenner

blowouts, buckling, support pull-out, or turbines and valves pushed off their supports.

Pipelines that are aboveground can shrink or expand dramatically over their length. From baking in the sun during the day to below-freezing temperatures at night, an aboveground pipeline can change temperature a great deal. If these temperature swings take place when the pipe is empty, the effect is even more dramatic. Keeping the pipeline full of water greatly limits the temperature change, but the one sunny day you need to drain the pipeline is the one that can cause you grief if you haven't accounted for the expansion.

Pipe material plays an important role in expansion and contraction. Plastic expands a lot more than steel pipe, and steel expands more than concrete pipe. Flexible pipe like polyethylene can absorb expansion by bowing, if there is enough room, but stiff pipe like steel is more likely to expand in a direct line against the thrust blocks or supports that hold it. For instance, a long plastic pipeline that lies straight and taut between two anchors when it is cold may need room to move back and forth between the anchors when it is warm. A straight steel pipe in the same situation may simply push apart the two end anchors when it expands.

The most common way to deal with expansion and contraction is to install expansion joints (an HDPE expansion joint is shown in the photo at left). These flexible couplings allow some movement of the pipe at the joint. The pipe must be securely fastened on either side of the joint to keep the joint from coming apart. There are formulas, published in the American Water Works Association's M series manuals on pipelines: steel, PVC, and HDPE, to help you figure out how much a pipe will expand or contract with given changes in temperature.

There are also some simple tricks. Put some unanchored bends in your pipe, since they will absorb a small amount of expansion and contraction. In some situations, you can anchor the pipe well enough to resist the effects of expansion and contraction. With plastic pipe, another option is to secure both ends and allow the pipe to bow or snake freely when it gets warm. However, make sure you secure the ends when the pipe is *cold*, not when it is warm, or it will shrink and pull the anchors together.

Keeping the concept of expansion and contraction in mind while designing your pipeline may help avoid some simple, but costly mistakes. Check out the AWWA (www.awwa.org) and other pipe manuals for basics.

Lee Tavenner, Solar Plexus • Missoula, Montana

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How to Buy a Wind Generator

by Mick Sagrillo & Ian Woofenden

Two veterans in the small wind industry give the straight scoop—no sugarcoating—on how to select the right wind turbine for your site.

Wind-electric systems draw a lot of interest from people who want to make their own renewable energy. We frequently get calls from folks who have seen advertisements for tiny turbines that can be mounted on a rooftop. For $5,000, the promise is that the wind turbine will provide all or most of your household's electricity. But don't be fooled into thinking that such equipment will do much more than light an exit sign. If you want a significant amount of energy, you need a rotor with significant swept area—it is, after all, the wind turbine's "collector." This article covers the serious machines—products with track records and warranties that have a realistic chance of generating enough energy for a home.

Sizing a wind-electric system is quite different than sizing a solar-electric (PV) system. With a PV system, you can add capacity as your needs grow or as you can afford more PV modules. But this is not practical with a wind-electric system. Theses systems are not incremental—you cannot install longer blades on your turbine, and upgrading to a larger turbine is not a possibility unless you engineered the original tower for it. The tower is often the most expensive part of the system, and is designed for one height and one turbine size. Installing an additional tower and turbine is very costly—it's better to have one tall tower with one large turbine. Most people make

a one-time investment and size their wind system to offset a significant portion of their electric bill.

Proper tower sizing is also critical, since the wind resource worth capturing exists well above buildings and other obstructions near the ground. Winds close to the ground are often weak and turbulent, and tall towers are essential to putting wind turbines where they can do their job properly. Contrary to many advertising claims for short towers, a tall tower also makes the system more cost effective. The standard industry rule is that the lowest point of the turbine rotor should be at least 30 feet above anything within 500 feet, and taller is better. On most sites, that translates to towers between 80 and 140 feet tall. Sometimes, even taller towers are required.

The essence of selecting a wind-electric system for a viable site is: "Buy a big collector and put it on a tall tower!" You will not find better advice on effectively capturing wind energy.

Scale

"Small wind turbines" cover an extremely wide range of hardware. On the lower end of the scale, you'll find turbines with rotors (turbine blades and hub) that are about 8 feet in diameter (50 square feet of swept area). These turbines may peak at about 1,000 watts, and generate about 75 kWh per month with a 10 mph average wind speed. Turbines smaller than this are known as "microturbines," which may be appropriate for sailboats, cabins, or other applications that require only a small amount of electricity. These are not covered in this article.

On the upper end of the scale, "small wind turbines" include turbines with rotors up to about 70 feet in diameter (4,000 square feet of swept area). These turbines peak at about 100,000 watts (100 kW), and generate about 8,000 kWh per month with a 10 mph average wind speed. Turbines of this scale are appropriate for farms, small businesses, schools, or institutions that use a lot of electricity.

The Northern Power Northwind 100 turbine is the largest turbine included in this guide, with a 69-foot-diameter rotor.

Courtesy www.northernpower.com

Bergey Windpower's XL.1 is the smallest turbine listed in this guide, with a rotor diameter of 8.2 feet.

Courtesy www.bergey.com

It's crucial that you know what your energy usage is so you can match the turbine's output to your energy needs. Don't guess: Measure your energy usage via your utility meter or other means. And then do the work to reduce your usage through energy-efficiency and conservation measures. Only then will you be ready to shop for the right-sized wind-electric system.

Reality Check

A current fad in small wind is the promotion of turbines that attach to your roof. However, these are invariably small—3 to 6 feet in diameter—and don't have enough collector area to make much electricity. In addition, many of these designs are half-baked ideas, "concept turbines," or one-off installations set up in an ideal location to attempt to optimize electrical output. Unfortunately, few small-turbine manufacturer hopefuls have any idea how much energy their turbine can generate at a given location for the prospective owner. Phrases like "a homeowner will save 20% to 80% off their electric bills" promise large generation potential with nothing to back up the inflated claims.

Many of these "urban turbines" are being installed in places that are well understood as compromised wind sites. Based on our experience, the 80-year history of small wind-electric turbine designs, and the current laws of physics and fluid dynamics, most of these systems will not work as hoped, nor ever generate meaningful amounts of electricity.

Many of these manufacturers are wildly optimistic in describing their products' performance—some bordering on outright fraud. An egregious example of this is a manufacturer claiming a turbine output of 30,000 kWh per year for a swept area comparable to the smallest of turbines we review in this article. That is an overestimate of at least 10 to 20 times the real production, based on a mathematical analysis of the rotor size and the laws of physics here on Earth that dictate the amount of energy available in the wind.

	XL.1	Whisper 200	Raum 1.3	Kestrel e300i	Proven 2.5 kW
Manufacturer/Importer	Bergey Windpower www.bergey.com	Southwest Windpower www.windenergy.com	Raum Energy www.raumenergy.com	Kestrel www.kestrelwind.co.za	Proven Energy www.provenenergy.com
Rotor diameter (feet)	8.2	9.0	9.5	10.0	11.5
Swept area (square feet)	53.0	63.5	73.0	76.0	103.0
Tower-top weight (pounds)	75	65	86	165	419
Predicted Annual Energy Output (kWh)*					
8 mph	681	794	908	950	1,864
9 mph	968	1,121	1,110	1,291	2,502
10 mph	1,301	1,483	1,539	1,652	3,215
11 mph	1,669	1,865	2,004	2,009	3,988
12 mph	2,061	2,254	2,479	2,341	4,805
13 mph	2,464	2,637	2,940	2,628	5,646
14 mph	2,866	3,005	3,365	2,863	6,492
Rpm	490	900	800	650	300
Generator type	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet
Governing system	Side Furling	Angle Furling	Tilt-Up Furling	Blade Pitching	Blade Pitching
Governing wind speed (mph)	29.0	26.0	23.0	27.0	27.0
Shut-down mechanism	Dynamic Brake	Dynamic Brake	Dynamic Brake	Dynamic Brake	Disc Brake
Battery voltages	24	24, 36, 48	24, 48	12, 24, 48	12, 24, 48
Controls included	Yes	Yes	Yes	No	Yes
Batteryless grid-tie version available	No	No	Yes	Yes	Yes
Phase configuration	Single	—	Single	Single	Single
Tower or installation included	—	—	—	—	—
Battery-based version cost	$2,790	$3,015	$3,650	$4,138	$10,500
Batteryless version cost	—	—	$3,650	$6,440	$12,650
Warranty (years)	5	5	5	2	5

*See page 44 for an explanation of data source/calculation.

Questions to Ask

So how do you compare one product to another? Begin by interviewing wind turbine manufacturers or dealers to assure yourself that what they are offering is more than a half-baked idea frosted with exaggerated and unverified promises. Here are some questions to ask:

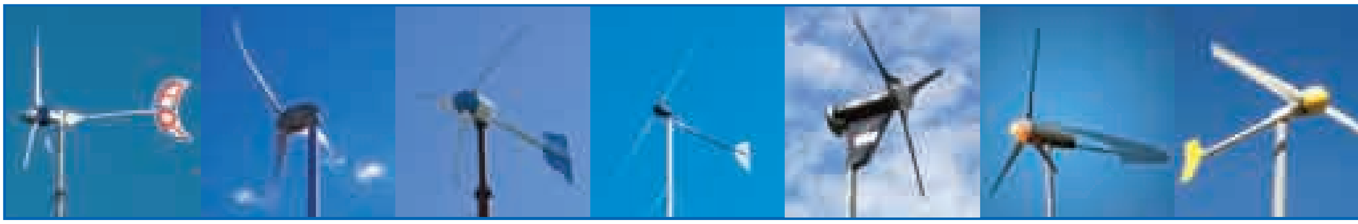
How long has the company been in business? While you may get a straight answer, expect some exaggeration that may include how long the company has been *thinking* about offering a wind turbine, as well as designing and testing the early prototypes.

How long has this turbine been offered as a production model, available for sale to ordinary consumers—not in the prototype or beta-testing stage?

How long was the prototype tested? Who did this testing? How many beta versions were sent to the field for feedback?

How many production models have been sold to ordinary consumers? Better yet, how many production models have been sold per year over the sales life of the turbine?

How many of the turbines sold are still running? (Don't laugh—one manufacturer continues to boast about the thousands



ARE110	Skystream 3.7	Kestrel e400i	Whisper 500	Proven 6 kW	Endurance	Scirocco
Abundant RE	Southwest Windpower	Kestrel	Southwest Windpower	Proven Energy	Endurance Wind Power	Eoltec
www.abundantre.com	www.windenergy.com	www.kestrelwind.co.za	www.windenergy.com	www.provenenergy.com	www.endurance windpower.com	www.eoltec.com
11.8	12.0	13.0	15.0	18.0	18.0	18.4
110.0	113.0	135.0	176.0	254.0	256.0	265.0
315	170	331	155	1,323	650	450
1,629	914	1,981	1,474	4,387	1,681	3,496
2,274	1,373	2,781	2,139	6,112	2,848	4,997
3,039	1,925	3,693	2,907	8,055	4,265	6,746
3,894	2,594	2,653	3,749	10,159	5,873	8,687
4,801	3,216	5,587	4,637	12,359	7,604	10,751
5,728	3,898	6,433	5,544	14,588	9,394	12,870
6,643	4,575	7,151	6,445	16,786	11,186	14,983
310	330	500	325	200	206	245
Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Induction	Permanent Magnet
Side Furling	Dynamic Brake	Blade Pitching	Angle Furling	Blade Pitching	Aerodynamic Stall Control	Blade Pitching & Stall Regulated
25.0	28.0	23.0	27.0	27.0	—	26.0
Dynamic Brake	Dynamic Brake	Dynamic Brake	Dynamic Brake	Disc Brake	Disc Brake	Dynamic Brake, Optional Blade Pitching
48	—	48	24, 36, 48	48	—	—
Yes	Yes	No	Yes	Yes	Yes	Yes
Yes	Yes	Yes	No	Yes	Yes	Yes
Single	Single	Single	—	Single	Single	Single
—	—	—	—	—	126 Ft. Tower	—
$11,800	—	$11,178	$7,810	$19,300	—	—
$12,650	$6,212	$13,328	—	$21,850	$39,995	$29,130
5	5	2	5	5	5	5

of turbines they have sold. Mick owns nine of them, all of which are broken and safely packed away in their boxes.)

How frequently has this model seen design changes or updates? What are those changes or updates? When were they incorporated? Were existing owners offered an opportunity to upgrade with the changes? At what cost? If the model has never been updated, why not?

Does the wind turbine meet the proposed American Wind Energy Association Small Wind Turbine Performance and Safety Standard?

What is the annual energy output for the turbine in average wind speeds of 8 to 14 miles per hour? How was this information developed? Has this ever been verified by an independent testing or reviewing agency from real-life installations? Or by a customer with a wind-speed data logger and kilowatt-hour meter? How and where?

Is there a performance guarantee for turbine output? (While such performance guarantees are a standard with wind farm equipment, this is a relatively new concept for

	Ventera VT10-240	Excel-R	Excel-S	ARE442	Proven 15 kW
Manufacturer/Importer	Ventera Energy www.venteraenergy.com	Bergey Windpower www.bergey.com	Bergey Windpower www.bergey.com	Abundant RE www.abundantre.com	Proven Energy www.provenenergy.com
Rotor diameter (feet)	22.0	22.5	22.5	23.6	29.5
Swept area (square feet)	380.0	397.0	397.0	442.0	683.0
Tower-top weight (pounds)	500	1,050	1,050	1,600	2,424
Predicted Annual Energy Output (kWh)					
8 mph	3,588	3,626	3,935	7,081	7,242
9 mph	5,262	5,401	5,663	9,910	11,393
10 mph	7,290	7,454	7,704	13,198	16,282
11 mph	9,661	9,712	10,043	16,819	21,700
12 mph	12,341	12,083	12,650	20,628	27,434
13 mph	15,266	14,475	15,479	24,483	33,284
14 mph	18,347	16,798	18,467	28,267	39,077
Rpm	270	310	310	150	140
Generator type	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet
Governing system	Blade Pitching	Side Furling	Side Furling	Side Furling	Blade Pitching
Governing wind speed (mph)	29.0	35.0	35.0	25.0	25.0
Shut-down mechanism	Dynamic Brake	Crank-Out Tail	Crank-Out Tail	Dynamic Brake	Disc Brake
Battery voltages	—	24, 48, 120, 240	—	Inquire	48
Controls included	Yes	Yes	Yes	Yes	Yes
Batteryless grid-tie version available	Yes	No	Yes	Yes	Yes
Phase configuration	Single	—	Single	Single	Single
Tower or installation included	—	—	—	—	—
Battery-based version cost	—	$24,750	—	Inquire	$41,500
Batteryless version cost	$16,800	—	$29,500	$39,600	$45,700
Warranty (years)	5	5	5	5	5

small wind. Don't expect an affirmative answer on this one, but it's worth asking about.)

How does one shut down the turbine in the event of high winds, when leaving on vacation for a week or so, or to perform maintenance? Is the shutdown mechanism reliable at any wind speed? What are the guidelines for shutting down the turbine in high winds?

What maximum wind speed is the turbine designed for? What about the tower? Has this been certified by a professional engineer?

Has the turbine ever gone through a reliability test? By whom? What was the duration of that test? What were the results?

What is the sound profile for the wind turbine at various wind speeds and distances from the tower? Who performed the acoustic tests?

How long is the warranty period for the turbine? What does the warranty cover? What is excluded? Is an extended warranty available?

What rate of warranty work has this turbine required? (Do not expect an answer to this question, as the response will

WTIC 31-20 Wind Turbine Industries www.windturbine.net	**EW50** Entegrity Wind Systems www.entegritywind.com	**Vestas V-15** Energy Mainten-ance Service www.energyms.com	**Vestas V-17** Halus Power Systems www.halus.com	**Northwind 100** Northern Power www.northernpower.com
31.0	49.0	50.0	56.0	69.0
754.0	1902.0	1964.0	2462.0	3725.0
2,500	5,340	9,920	14,065	16,100
7,295	19,452	22,010	37,820	54,094
10,689	31,856	33,514	54,966	76,375
14,966	47,164	46,543	75,165	102,291
20,066	64,819	60,536	97,850	131,059
25,836	84,195	75,004	122,375	161,780
32,070	104,673	89,546	148,090	193,571
38,552	125,669	103,834	174,371	225,619
175	62	53	45 – 50	59
Brushless Alternator	Induction	Induction	Induction	Permanent Magnet
Blade Pitching & Side Facing	Stall Regulated Airfoil	Motor Yaw	Motor Yaw	Electronically Stalled & Dump Load
25.5	—	—	—	33.5
Disc Brake	Tip Brakes & Park Brake	Motor Yaw & Disc Brakes	Motor Yaw & Disc Brakes	Dynamic & Disk Brakes
—	—	—	—	—
Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes
Single	Three	Single	Three	Three
—	120 Ft. Tower & Installation	110 Ft. Tower & Installation	132 Ft. Tower & Installation	120 Ft. Tower & Installation
—	—	—	—	—
$43,225	$225,000	$180,000	$220,000	$425,000
1 (5 Available)	5	1 (5 Available)	1 (5 Available)	2 (5 Available)

How Did We Choose?

It was a tough job to decide which wind generators to include in this article. There are many models and manufacturers to choose from, but ultimately we wanted to promote machines that will serve *Home Power* readers well.

We've included turbines that meet these criteria:

- Home-, farm-, business-, and school-scale, with swept areas ranging from 50 to 4,000 square feet
- Sold and supported well in North America, with dealer network
- Have third-party verified energy data
- Have published pricing, warranty, and track records
- Authors consider the manufacturers to be long-term players in the small wind industry

—Ian Woofenden & Mick Sagrillo

likely be that this is proprietary information. Regardless, it is worth asking simply for the reaction you will get.)

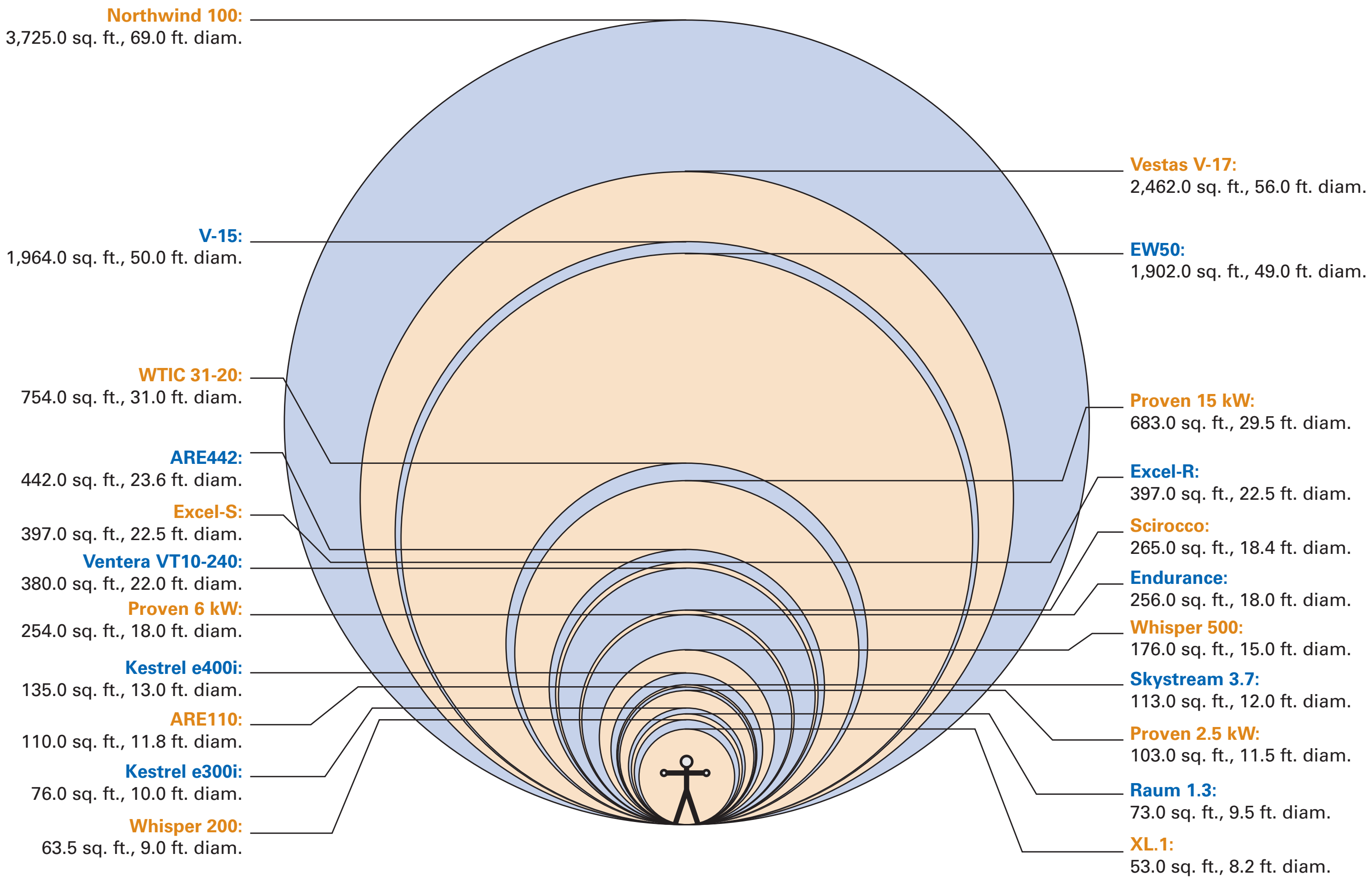
What problems in the field have been identified? How has the company dealt with them? Have any recalls or updates been issued as a result of these problems? Who does the work to remedy the problem? Who pays for this work?

Are there local any installers who can install this wind turbine? Preferably, they can recommend more than one installer so that you have some choices. In addition, an installer who also works with other manufacturers' equipment is preferable, not because you are shopping for a different turbine, but because this gives the installer the advantage of having a well-rounded "education."

Wind Turbine Specifications

The tables show basic specs for viable small wind turbines available and supported in North America. Understanding the specs will help you make intelligent choices when it's time to buy your turbine.

Blade Diameters & Swept Area



Manufacturer/importer. In some cases, the wind turbines are either remanufactured or imported. For imported models, the North American contact is listed.

Rotor diameter is a typical identifier for turbines, although using the swept area would be handier. The difference between a turbine with an 8-foot diameter and one with a 10-foot diameter might not seem large, but it represents a 58% increase in collector size, with a proportional potential increase in energy output.

Swept area of the rotor is the area in square feet of the circle "swept" by the blades. This is the "wind collector" and, besides your site's average wind speed, is the single largest factor influencing turbine output. A larger rotor will give you more energy, all other things being equal (and they usually are).

Tower-top turbine weight may give you an idea of turbine durability. Although weight itself doesn't necessarily translate into turbine longevity, a heavier turbine often means a more durable machine.

Annual energy output (AEO) for 8 to 14 mph gives general energy production to match to your site's average wind speed and your home's energy needs. Your turbine's performance on your site may vary, sometimes significantly. Be conservative by choosing the next larger turbine when you're not sure of your exact energy use or if the exact size of turbine you need is not available. Also, AEOs apply to locations from sea level to 1,000 feet in elevation and must be adjusted for lower air density at higher altitudes. Your installer or turbine manufacturer can help you crunch these numbers. All AEOs in the table are derived by the authors from manufacturers' data using the following assumptions:

- 1,000 feet above sea level
- Derated 5% for inverter-based systems
- 0% derating for induction generators
- No derating for turbulence at the site. (A more accurate estimate would be to derate the AEO by 15% for turbulence at a well-exposed, elevated site; 20% for a site with fencerows and buildings, but average exposure relative to the surrounding terrain; and 25% for a more cluttered site with nearby trees, houses, and other buildings.)

AEO was calculated using the 7th Wind Output Calculator, a version of WindCAD, with performance determined based on the power curves supplied by the manufacturers for this purpose.

Rpm is the blade revolution speed at the turbine's rated output and relates to two factors in wind generators: durability and sound production. In a given class of turbines, a slower

Understanding Turbine Rating

Wind turbine ratings are the most often misunderstood specification in the small wind industry. Unlike PV ratings that are standardized at 1,000 watts per square meter at 25°C, small wind turbines currently have no such standard. As a result, one wind turbine might be rated at 10 kW in a 25 mph wind, while another might carry the same rating, but at 32 mph. Because the power available in the wind increases with the cube of the wind speed, a turbine rated at 10 kW at 32 mph would only be rated at 5 or 6 kW at 25 mph. That's one reason why using rated power as a performance measure is deceptive at best.

Our suggestion is to ignore the kW rating for wind turbines. Instead, look for documentation of the annual or monthly energy output. Since you are likely to install only one wind turbine, it makes sense to shop for a turbine that will generate the amount of electricity you consume. The kW rating does not and cannot tell you this.

The American Wind Energy Association is developing a standard for small wind turbines to meet when marketed and sold. The standard will include a kW rating at a standard 25 mph, not at an arbitrary wind speed determined by the manufacturer. Much more important will be standardized energy (kWh) estimates, which will put all turbines on a level playing field.

rotor speed will generally mean a longer-lasting turbine—less wear and tear on the rotating parts. It also usually means a quieter turbine. Note that lower rpm does not mean lower production, nor does higher rpm mean higher production. In both cases, the alternator is matched to the rotor speed to get as much energy out of the wind as possible.

Governing system describes the method the turbine uses to shed excess energy in high winds to protect the turbine from overspeeding. Some turbines tilt or "furl" the rotor directly up or to the side, while others furl at an angle. Still others use blade pitch control, turning the blades out of their optimum aerodynamic angle so that they don't capture as much energy. Blade pitching more reliably protects the wind generator, but this feature costs more than machines that furl (due to more moving parts and complexity).

Governing wind speed is the point at which the turbine starts governing. A low governing speed suggests that the turbine designer was conservative—more interested in long-term reliability than inflating peak output and squeezing a bit more energy out of infrequent high winds.

Shutdown mechanism is different from governing, and refers to a method to stop the turbine for servicing, in an emergency, or when you just don't need the energy. Many small turbines have no mechanical means to shut them down. Instead, they rely on dynamic braking (electrical shorting of the permanent magnet alternator windings), which does not always work, especially when needed in higher winds. Mechanical brakes are usually more reliable than dynamic braking. Generally, larger and more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms.

Battery voltages are listed for battery-charging turbines so you can choose the right turbine voltage for your battery bank. Most modern, whole-house, battery-based RE systems use a 48 V battery bank with an inverter to supply the house with 120 or 240 VAC.

Controls included are what you get when you buy the turbine—such as a controller, a dump load, and/or metering. These components are specific to the turbine and can be expensive, so don't forget to add them into your calculations if they are not included.

A Vestas V-15 rotor being installed on the turbine by a crew of four.

Courtesy www.seventhgenergy.org

Batteryless grid-tie tells you whether the turbine is available in this configuration, which is normally the most efficient choice. If you're determined to have protection for utility outages, all battery-charging turbines can be grid-tied via a battery-based, grid-tied inverter. But this approach will incur inefficiencies and additional cost.

Phase configuration. For grid-tied applications, all wind turbines sized up to and including the Jacobs 31-20 are for single-phase electrical services, the standard for homes in the United States. Turbines larger than the 31-20 must all be connected to a three-phase utility service, usually available to larger electrical customers. The Vestas V-15 is available as both single-phase and three-phase.

Cost is for the turbine and any included controls. Remember that the turbine is only one component in the system—and usually not the most expensive one. A tower, batteries, and inverter each can exceed the turbine cost. Note that the EW15, EW50, V-15, V-17, and Northwind 100 turbines also include tower, wiring, all installation materials, and labor costs.

Warranty is an indication of the manufacturer's confidence in the machine, or is set to meet the requirements for incentive programs in states such as California. Find out what is covered—usually it's equipment only, and not the costs of replacement *labor*, which can be significant. Several of the manufacturers that offer shorter than five-year warranties will extend the warranties for an additional cost.

What we're not listing is rated or peak power. That data is close to meaningless and a distracting marketing ploy. One cannot accurately predict annual energy output (which is what you want to know) from rated power, since two machines with similar peak power can give very different energy outputs. (See "Understanding Turbine Rating" sidebar.)

Newcomers we're not listing. There are several promising "newcomers" to the North American wind scene that deserve a closer look as they further develop their presence or their products. These include Aerostar from Massachusetts, Gaia-Wind (Denmark), Iskra (UK), Fortis (New York), PGE (Canada), and African Wind Power (South Africa).

Selecting Your Turbine

We firmly believe that small wind is part of the energy solution. However, there are numerous companies now in business, selling everything from ideas and investment opportunities to beta systems and equipment they know full well will not or cannot work. This has been spurred on by the state public benefits programs combined with the federal investment tax credits for homeowners. Everybody wants to cash in, and this is a problem.

There are numerous turbine-purchasing opportunities available. One survey of the small wind industry stated that 35 manufacturers or importers now sell 102 different turbines in North America and 11 more plan to sell turbines within three years. One look at the accompanying table reveals far fewer viable choices. Rather than tell you what *not* to buy, we can tell you which turbines we think might make good investments.

To select your turbine, you need two critical numbers. First, you need to know what your wind resource is at "hub height"—where the wind generator will live. You're looking for the average annual wind speed. For most viable home sites, that number will be in the range of 8 to 14 miles per hour. A professional site assessor can give you a good idea of your wind resource, or you can do the research and legwork yourself if you're motivated, educated, and have the time.

The other number you need is the amount of energy you want to generate. You're looking for kWh per day, month, or year. You can find this on your utility bill or by performing a more detailed analysis of your home's loads. From this, you can calculate your annual energy consumption. We encourage you to put time and money into reducing this number instead of installing a wind generator to make energy that will be squandered by inefficient appliances.

With these two numbers, you can begin your search for the *best* wind generator options for your site and match a turbine to your needs at your tower-top average annual wind speed. Notice we didn't say "perfect"—all wind generators will need regular inspections and maintenance, and most wind generators will need repair or replacement over time. These machines have a tough job to do in a very harsh environment.

If you do your homework and choose carefully, you'll have taken the first step toward building your system. Keep in mind that a complete system involves many other components, and *all* are necessary to actually generate wind electricity. Though these systems are complex and can be expensive, designing, installing, maintaining, and living with your own wind-electric system can be entertaining, satisfying, and rewarding.

Access

Mick Sagrillo (msagrillo@wizunwired.net) has pondered wind generators in northeast Wisconsin for nearly 30 years.

Ian Woofenden (ian.woofenden@homepower.com) gets high on life and towers in northwest Washington and beyond.

Recommended Reading:

"How To Buy a Wind-Electric System," 2007 edition, Ian Woofenden & Mick Sagrillo, *HP122*

"Anatomy of a Wind Turbine," Ian Woofenden & Hugh Piggott, *HP116*

"Wind Electric Systems Simplified," Ian Woofenden, *HP110*

"Wind Generator Power Curves," Ian Woofenden, *HP127*

"Wind Generator Tower Basics," Ian Woofenden, *HP105*

"Estimating Wind Energy," Hugh Piggott, *HP102*

INVERTER EVOLUTION
2002
Parallel
Stackable
2006
120/240VAC
Split Phase
2009
Apollo Solar
Delivers...
Parallel Stackable, Split Phase,
2200 to 3600 VA, True Sine Wave
Off-Grid Inverter/Charger
ADDITIONAL SYSTEM OPTIONS...
Easy to Install
Switchgear Module
Local and Internet
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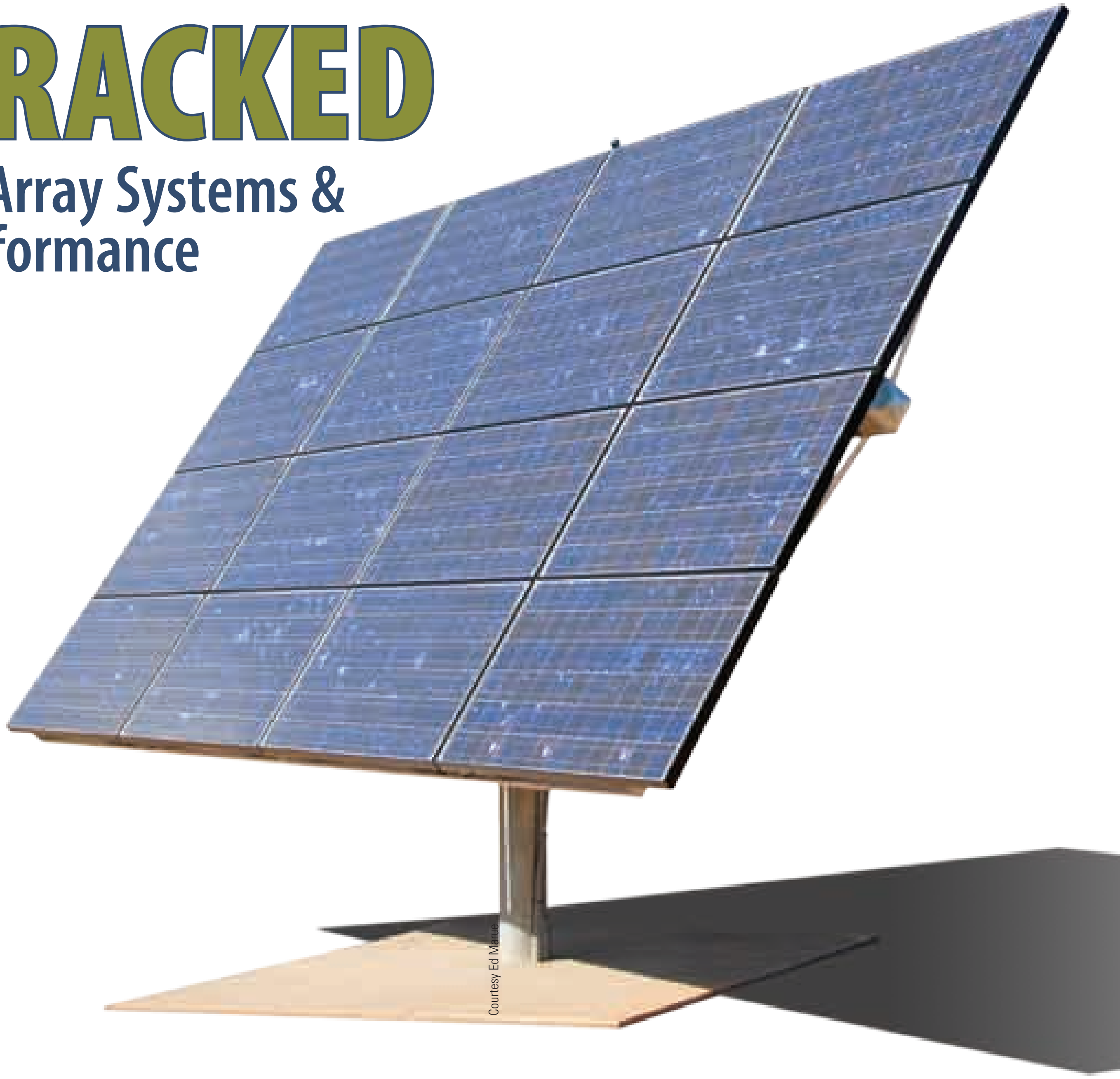


by Justine Sanchez

Whether it's hitting the road in sleek speedsters (electric, of course), surfing the powder on snowboards, or pounding the trails on mountain bikes, most of us love being in motion. Even those who consider themselves untethered to mainstream thrills are often mesmerized by the spinning blades of a wind generator or the swiftly moving waterways powering a microhydro turbine. But there's not much excitement in a fixed photovoltaic array in action—beyond watching the electrical meter spin backward.

Because they don't rely on moving parts to produce electricity, most PV arrays do their job without much fanfare or fuss. However, PV modules produce the most power when they are aligned perpendicular to the sun's rays, and since the turning Earth moves the sun across the sky, the *only* way to do this is to put the array in motion by using a tracking device. Under the right circumstances, tracked PV arrays can intercept much more sunlight than stationary PV arrays. While exact performance numbers will vary depending on the site location and system specifics, trackers typically can increase overall energy production by 25% to 40%.

Tracker Types

Trackers are divided into two groups: active and passive. Most active trackers use an optical sensor to determine the sun's position, and an electronic control and one or more motors to position the array. Single-axis active trackers are set to a fixed tilt angle (which can be adjusted seasonally) and then track the azimuth angle of the sun across the sky.

Left: A Zomeworks single-axis tracker with its outboard Freon vessels. Right: A Wattsun tracker (note the optimal sensor in the upper left corner of the array).

Dual-axis devices track both the sun's azimuth and altitude angle (its angle to the horizon), and offer the most accurate tracking, but cost more (see "Cost of Tracking" table on page 54). Active trackers are susceptible to damage from nearby lightning strikes, which can damage the motor and controls.

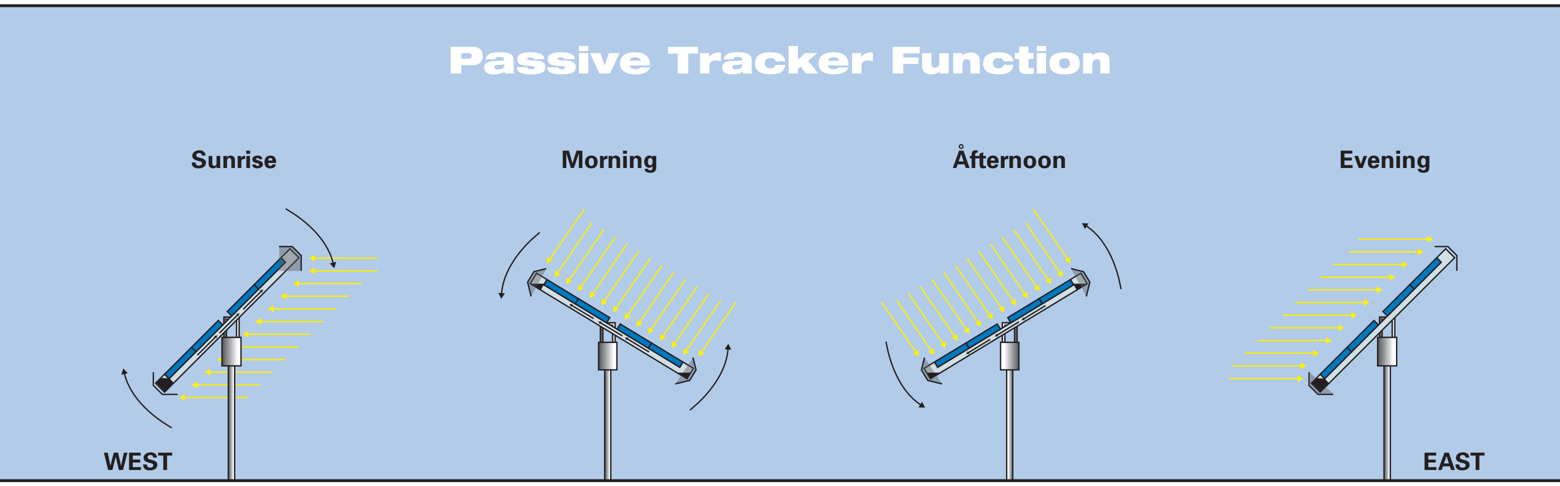
Passive trackers use the heat from sunlight to vaporize liquid Freon contained in canisters mounted on the tracker. As the gas expands, it forces the liquid to the canister on the other side of the tracker, and the change in weight causes the rack to move. Passive trackers are single-axis and will follow the sun from east to west. These trackers will not track the altitude angle of the sun but can be tilt-adjusted seasonally. The primary advantage to passive trackers is that they do not depend on electric motors or controls to function. However, because they are thermally controlled, and dependant on the intensity of incoming sunlight, these trackers may have difficulties in extremely cold climates, and/or in hazy conditions, when delayed heating can reduce overall energy production.

Tracking Pros

Because tracking arrays receive more peak sun-hours, energy production is improved. This allows a smaller array to be installed, shrinking the required array footprint—a benefit for sites with limited space.

Sites with wide-open solar access (shade-free from dawn to dusk with low horizons) can benefit the most from a tracking array, wringing every last electron from the sun over the seasons. The energy gained during early morning and late evening hours can be significant—especially during long

From left to right: Incoming sunlight warms the canisters unevenly. In the exposed canister, liquid Freon vaporizes and expands. As the gas expands on one side, it forces the liquid from one canister to the other; the change in weight causes the tracker to move the array.



AC Energy Comparison for 4 kW Fixed vs. Tracking PV Systems in Tucson & Seattle

	Tucson, Arizona					Seattle, Washington				
	Fixed Array		Dual-Axis Tracking Array			Fixed Array		Dual-Axis Tracking Array		
	Insolation*	kWh	Insolation*	kWh	Increase	Insolation*	kWh	Insolation*	kWh	Increase
Apr.	7.50	625	10.64	900	44.0%	4.37	383	5.57	499	30.3%
May	7.29	605	11.27	953	57.5%	5.31	471	7.15	647	37.4%
Jun.	7.15	567	11.38	918	61.9%	5.52	467	8.03	697	49.3%
Jul.	6.44	526	9.25	768	46.0%	5.88	508	8.65	765	50.6%
Aug.	6.85	565	9.67	810	43.4%	5.17	448	6.85	604	34.8%
Sep.	7.06	573	9.51	783	36.6%	4.98	419	6.57	565	34.8%
Total: Spring/Summer		3,461		5,132	48.3%		2,696		3,777	40.1%
Oct.	6.72	577	8.96	779	35.0%	3.00	263	3.57	317	20.5%
Nov.	5.99	515	7.85	675	31.1%	1.76	148	1.96	168	13.5%
Dec.	5.27	480	6.92	630	31.3%	1.26	103	1.38	115	11.7%
Jan.	5.70	513	7.55	685	33.5%	1.54	133	1.74	153	15.0%
Feb.	6.11	485	7.99	640	32.0%	2.50	201	2.85	232	15.4%
Mar.	7.03	620	9.48	843	36.0%	3.71	335	4.50	411	22.7%
Total: Fall/Winter		3,190		4,252	33.3%		1,183		1,396	18.0%
Annual Ave.	6.59		9.21		41.1%	3.76		4.91		33.4%
Annual Totals		6,651		9,383			3,879		5,173	

*Average daily peak sun-hours
Source: PVWatts (www.nrel.gov/rredc/pvwatts/)

summer days when, at many northern latitudes, the sun rises in the northeast and sets in the northwest.

Tracking Cons

One of the benefits of PV technology is that the modules don't *need* to move to produce electricity—it's one of the reasons why solar electricity is such a reliable form of power. Whenever moving parts are introduced, the likelihood of component failure—and the need for periodic maintenance—increases.

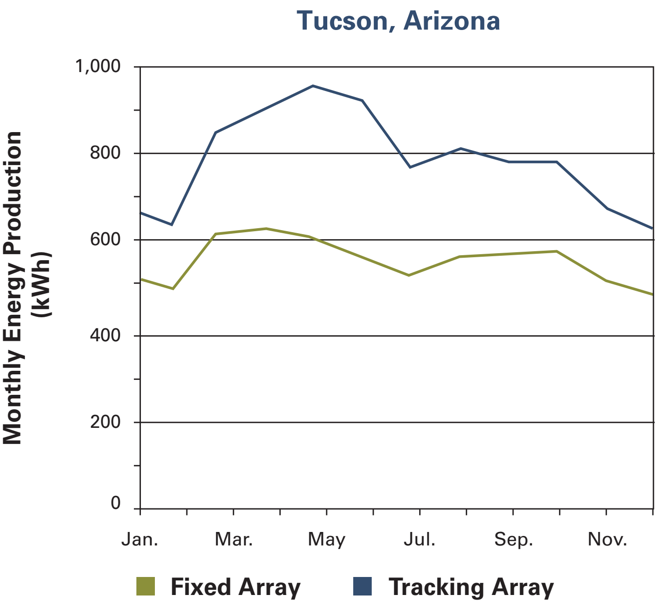
If a tracker stops functioning, to keep your array producing optimally, you'll need to manually position the array at an appropriate tilt angle and face it to solar south. Defunct electronically controlled trackers can be positioned with manual controls (an option at purchase). A passive tracker can be positioned by hand and secured into place by attaching ropes or ratcheting straps to fixed points provided at the four corners of the rack and tying down to fixed points placed on either the pole or in the concrete pad.

A potential disadvantage of purchasing a tracked system is that some PV rebate programs are based on the size of the PV array (installed watts) rather than PV array energy production. This means that the overall cost benefit of the tracking system could be reduced, depending on how incentive programs are structured. For example, at your site

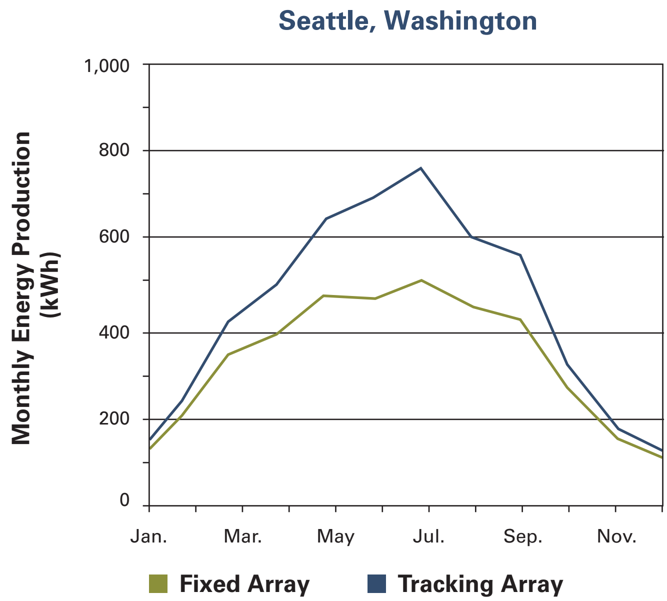
A dual-axis tracker continually adjusts for optimal exposure, including low winter sun angles.

Courtesy www.big-thunder.com

Fixed vs. Tracking Array Energy Production



Note: 4 kW array; fixed array facing south at 32.1° tilt. Source: PVWatts



Note: 4 kW array; fixed array facing south at 47.5° tilt. Source: PVWatts

you might calculate that a 3 kW tracked array will produce as much power as a 4 kW fixed array. However, your local utility offers a $4 *per installed watt* rebate. Here's the catch: Even though the up-front cost of the tracked system is lower, instead of a rebate check for $16,000, you'll get only $12,000, since the rated wattage of your array is smaller. In this case, while the energy production of each array would be about the same, the system cost after the rebate would be *less* for the fixed PV array. Note that many areas have or are moving to production-based incentive programs, which make payments based on energy produced instead of installed watts. Check on available incentives with the Database of State Incentives for Renewables & Efficiency (www.dsireusa.org).

Best Applications

Extra power is only beneficial if you can use it, sell it, or store it as it is produced. A grid-connected system with a wide-open solar window can be a good candidate for a tracked array, since every kilowatt-hour gets used and, in net-metered situations, is credited to your utility bill. An off-grid system with daytime summer-dominated loads (like irrigation) is another good candidate for a tracking array.

A tracked PV array provides electricity for growing plants and rearing fish in the dome structure behind it.

Courtesy www.brotherselectricsolar.com (2)

Cost Comparison of Fixed vs. Tracking PV Arrays

	Tucson, Arizona			Seattle, Washington		
	Fixed Pole Mount	Passive Single-Axis Tracking	Active Double-Axis Tracking	Fixed Pole Mount	Passive Single-Axis Tracking	Active Double-Axis Tracking
System size (W)	4,000	3,000	2,850	4,000	3,200	3,000
System production (kWh/yr.)	6,651	6,624	6,686	3,879	3,905	3,879
Estimated system cost*	$34,400	$27,390	$28,500	$34,400	$29,216	$30,000
Cost per kWh produced annually	$5.17	$4.13	$4.26	$8.87	$7.48	$7.73

*Assumptions: Installed system costs per W = $8.60 for fixed, $9.13 for single-axis passive; $10 for double-axis active

Water-pumping systems are also ideal candidates for PV-direct tracked arrays. Because these systems often do not have batteries that would allow for water-pumping when the sun is unavailable, there is a need to pump as much water during daylight hours as possible, and a tracking array can take full advantage of the available sunlight. These systems offer inherent synergy, matching the seasonal needs for water pumping (for livestock and crops) with the longest daylight hours.

If you have an off-grid system with *winter*-dominated loads, a tracked system may not yield the best cost benefit. This is largely due to two issues. First, off-grid systems often cannot put excess power to work—if the batteries are full, the charge controller will simply shut off the PV array. Second, for most off-grid homes, energy use is highest in the wintertime—so systems are often sized for that season—yet the extra energy from a tracking array is most available in the summertime.

Costs

Given the right circumstances, tracked PV arrays can be a good design strategy, but at what cost? The answer to this question depends on several factors, including system size, solar access, and system type. See the "Cost" table (above) for a cost comparison of fixed versus tracking PV systems. Although the table shows that up-front system costs can be less expensive for a tracked system (even in areas like Seattle), this cost comparison does not include additional maintenance costs or savings from incentive programs. As noted, if the rebates are based on installed watts, this could make a *fixed* PV array less expensive.

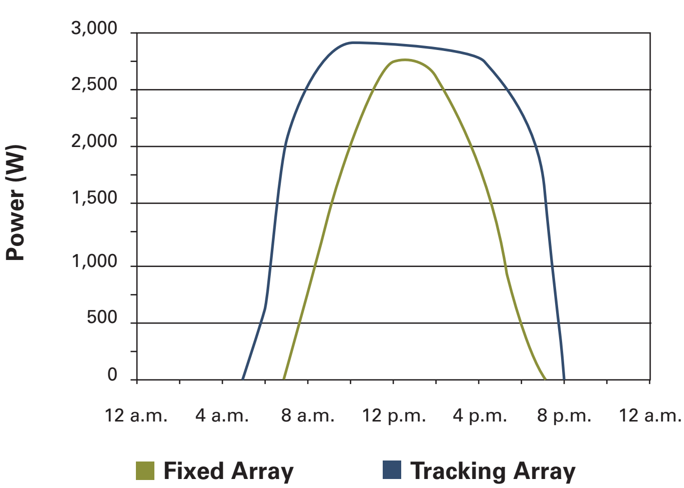
Installation Considerations

Tracking arrays, like all pole-mounted arrays, are like big sails: Set several feet above the ground, they can experience significant wind-loading. To keep them in place, arrays are usually mounted on large poles (6 to 8 inches in diameter, or even bigger for taller poles), which must be set in large concrete footers.

Tracker components, especially the drive assembly for electronically controlled trackers, can be heavy, tipping the scales at more than 200 pounds. Often, they'll need to be placed with a crane, backhoe bucket, or some other mechanical means.

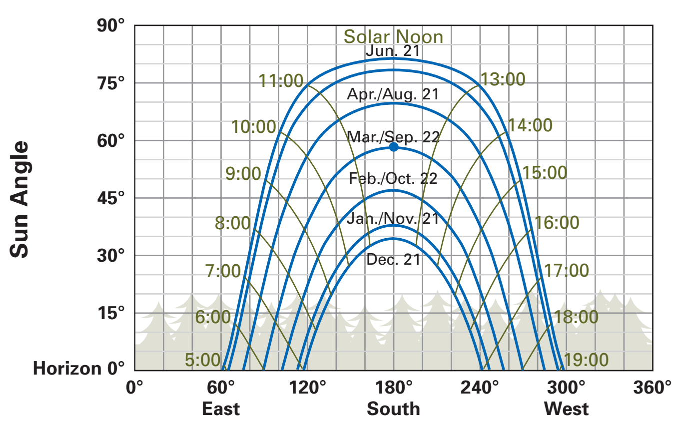
(continued on page 56)

Single-Day Production: Fixed vs. Tracking Array



Note: 4 kW array; fixed array facing south at 32.1° tilt. Source: PVWatts. Daily power values calculated for average insolation values for May 19.

Sun Path in Tucson, AZ



Tuscon, AZ: Latitude, 32°; Longitude, -111°

Tracking Success

Home builder Ed Marue offers his perspective on making the most of his PV energy production with tracked systems operating in two very different climates.

The conditions for the remote, off-grid installation were ideal—a seasonal residence on a wide-open property that takes advantage of the long summer days in central Idaho, when the sun makes a sweep from 15° north of east to 20° north of west, with more than 11 peak sun-hours daily. Under these conditions, the 960-watt PV array easily keeps the 1,000 amp-hour battery bank charged, powering a 1,000-square-foot cabin equipped with lighting, a washer, a TV, a computer, a vacuum, and a dishwasher. Because of the ample energy the batteries receive from the array, rarely does the battery state of charge drop below 70%.

The system—eight Kyocera KC120 modules and an AZ-125 Wattsun dual-axis tracker—was easy to install and has worked perfectly. A pyramidal sensor mounted on the array signals the electronic controller, which powers the DC azimuth drive motor and elevation actuator, always keeping the array perpendicular to the sun. The tracker has weathered six summers and winters, and temperatures of 112°F to -10°F, with no repairs or maintenance, other than greasing the gear head each spring. In the winter, the array is left unattended, and power to the controller is shut off with the tracker pointed due south at a steep angle to shed snow more easily. Because there is no requirement for power during the winter months, the decision to install a tracker, rather than a more costly, larger, fixed PV array, has proven to be a wise choice.

A pair of 2,720 W pole-mounted, tracked arrays at the Tucson site have generated even more energy than originally predicted.

With a wide-open summertime solar window, this small dual-tracked array produces enough electricity for the seasonal residence.

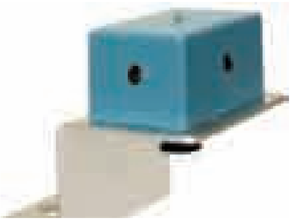
Courtesy Ed Marue (3)

The grid-tied installation in Tucson, Arizona, also had a wide-open site, but there were no good roof-mount options—the design of the home minimized southern exposure to decrease cooling loads. So two Wattsun AZ-225 trackers, each with 16 BP SX170 modules, producing a total of 5,440 watts of PV, were chosen. The trackers installed easily, and other than an initial problem with an elevation drive motor that had intermittent brush contact, there have been no reliability issues in the 18 months since commissioning. The manufacturer's documentation was clear and concise, and the company was extremely responsive in resolving the initial problem, which required a replacement motor. The array has produced 13,174 kWh in its first year of operation, slightly more than predicted.

The system was installed during the home's construction, and on-site labor for the array installation was not separately accounted for. Excluding labor, the gross cost of the system was $42,247, with a net cost of $25,927 after a $16,320 utility rebate. An equivalent 7.65 kW fixed array was estimated to have cost $27,847 after rebate.

—Ed Marue

The eyes of a dual-axis tracker: Four photocells sense sunlight, signaling the tracker to keep exposure consistent.



Optional manual controls for a Wattsun tracker allow easier setup and troubleshooting.

A complete pole-mounted PV system: 12 Sharp 380 modules on a Wattsun dual-axis tracker, an SMA inverter, and other balance of system components.

Courtesy www.wattsun.com (3)

When installing module home-run wiring, leave lots of wire length from the modules to the junction box on the pole. This will ensure that when the tracker is in its farthest positions the cables are not pulled tight. (Bundle these cables together with zip ties to keep the installation as tidy as possible.)

Electronically controlled trackers have an optical sensor that needs to be mounted at the top of the array. Also, a tracker controller needs to be mounted on the drive and powered either by the battery bank or AC power, if available. In the latter case, a switching power supply, another option at purchase, converts AC to DC to power the DC tracker controller. In either case, a power line needs to be appropriately planned for and run from the power source to the controller. Although the controller can be powered directly from the PV array, this option is discouraged—because there's no power available from the PV array after sunset, the tracker must wait until the next morning to turn back to face the sun. During the summer months, the optical sensor can get confused as to which direction it should return, since it will end up pointing northwest in the evening. Tracker rotation must be limited to 180° to avoid this confusion. However, this limits the energy gain the tracker can yield in the summer months, since the sun's azimuth angle exceeds 180°.

The decision to invest in a tracking PV array is a personal one based on budget and your willingness to deal with possible maintenance (or even repair) issues, since moving parts can break down. In the right circumstances, though, tracking systems can save money up-front and keep you on track to greater energy production.

Homebrewed Trackers

Some active trackers use clockworks to approximately follow the sun's azimuth. Normally a homebrew solution, these clockworks need to be manually set each morning to face the rising sun before being powered up. As a result, they are not quite as accurate as trackers that employ optical controls.

Tracking can be even more inventive, and the *Home Power* crew has seen it all—from arrays mounted on a turntable with ropes on opposite sides so that the system owner can move the array by manipulating the ropes from inside the home, to a water-powered tracker that moved by the changing weight of water-filled buckets purposefully built to leak at a specific rate. Way back in *HP17*, we included an article on how to build your own photo-sensor controller to operate a 12 VDC windshield wiper motor to turn an array. This controller could also operate a modern actuator to move the array.

Tinkerer beware: One problem with manual tracking is that neglecting to move the array means that modules could spend a large part of the day faced *away* from the sun—resulting in the exact opposite of the desired effect.

Access

Justine Sanchez (justine.sanchez@homepower.com) is a NABCEP-certified PV installer, *Home Power* Technical Editor, and Solar Energy International instructor. Justine dreams of one day installing her own tracking PV array, but for now lives, works, and teaches from an on-grid, fixed-mounted, PV-powered home in Paonia, Colorado.

Ed Marue (emarue@msn.com) holds a bachelor's degree in physics. He's the principal of Solar Lava Development Corp., a sustainable architecture company, and the former owner of Tri-Ex Tower Corp. and chipmaker High Voltage Devices.

Tracker Manufacturers:

Array Technologies • www.wattsun.com

Small Power Systems • www.smallpowersystems.com

Zomeworks Corp. • www.zomeworks.com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Solar Power SHINES in New Orleans

by Kelly Davidson
photos by Jan Clifford & Phillip Neal

In October 2005, only weeks after Hurricanes Katrina and Rita consecutively blasted the Gulf Coast, Phillip Neal and Jan Clifford returned to their home in the Mid-City section of New Orleans. "It was pretty sobering. We stood there and cried for about 20 minutes," Phillip recalls. "Then, we did what we had to do—started cleaning up."

More than 4 feet of floodwater had infiltrated the historic neighborhood, which sits on a slender finger of land between the Mississippi River and Lake Pontchartrain. Fortunately, the neighborhood's characteristic shotgun-style homes—slender boxes, typically one-room wide—are made of local cypress, which dries out quickly, and built higher off the ground on piers to resist flood damage. That simple yet sturdy construction spared most homes from total destruction. Still, some suffered water damage from roofs that were breached during the hurricanes' winds. But it was the compromised

Facing page, top: Phillip Neal, atop his solar-electric roof.

Facing page, bottom: The solar energy systems at the Neal-Clifford residence do not detract from the home's charming streetside character.

The back porch roof had just enough room for two solar collectors. The staging balcony was left in place to make future system maintenance easier.

natural gas and power lines, as well as plumbing and sewer systems, that posed the greatest challenge to the rebuilding efforts after the storms.

Several obstacles to restoring utilities throughout the city reared their heads. In Mid-City, as in other areas, the wiring and plumbing in many of the older homes had to be brought up to code before utility services could be reconnected. "With a shortage of plumbers and electricians, that was no easy feat," says Phillip, who works as an inspector for an engineering firm. "It took some people a year or more to get the work done and return to their homes."

Solar Motivation

"With one look around the neighborhood, it was clear that we were one of the lucky ones," Phillip says. "A few of the homes had to be torn down."

In contrast, Phillip and Jan's home suffered only minor damage. Structurally, the 2,400-square-foot double-shotgun held up well against the storms' ravages. Boarded up with the original shutters, all the windows survived. But the saving grace was the new standing-seam metal roof they had installed five years prior. The decision, Phillip says, was largely based on research from the Florida Solar Energy Center (FSEC), which suggests that metal roofs provide greater energy efficiency compared to ordinary composition roofing. But it was a 50-year manufacturer warranty, a wind rating of 125 mph, and a UL-90 wind-uplift rating (the highest in the industry) that sealed the deal, giving the couple the peace of mind and hurricane protection they needed.

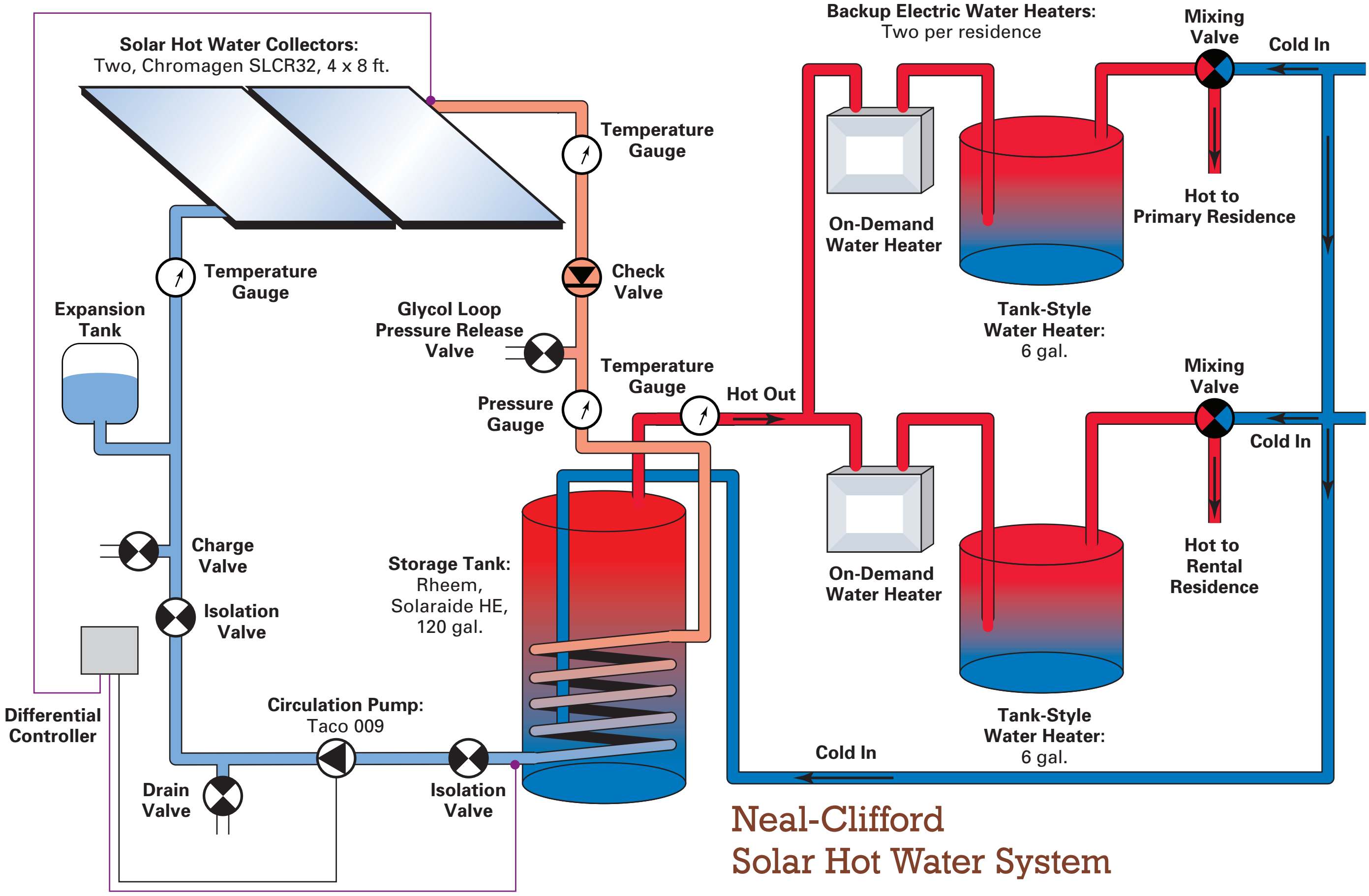
The decision proved to be a wise one all on counts. The Permaseam metal roof remained intact through the storms' high winds and heavy rains, with only a few "bumps and bruises." And, in the calms before and after the storms, the white surface does as Phillip had hoped it would—reflects a significant portion of solar radiation to minimize heat gain in the attic and reduce demand on the central air-conditioning system.

Fifty-seven-year-old Phillip has been keeping tabs on the solar energy movement ever since the energy crisis of the '70s. Though he'd done what he could to improve the efficiency of his home over the years—sealing holes in the building envelope, installing ceiling fans to decrease the air-conditioning load, replacing the insulation in the attic, and switching to efficient compact fluorescent lights—it wasn't until after Hurricanes Katrina and Rita that he got serious about solar energy.

"The storms put the fear of reality in me. Watching the government's insulting response and having to wait two months for our utilities to be restored was all the convincing I needed," Phillip says. "I knew then that I needed to take control over my living situation and be more self-sufficient for the next time—because there will be a next time."

Shortly after the storms, the renewable energy movement finally started to gain momentum in Louisiana. Helping the cause were the millions of homes throughout the state that were left without grid-connected electricity for several months—longer in harder-hit areas. Like the rebuilding efforts, progress was slow. But all the political wrangling gave way in July 2007 to a generous incentive—a 50% state tax credit toward the first $25,000 spent on any residential RE system—solar hot water, solar-electric, solar pool heater, or wind generator.

The new incentive, coupled with the federal tax credit, made it possible for Phillip and Jan to move forward with not just one, but *two* grid-connected solar-electric systems with battery backup. Since they rent out half of their double shotgun, they could essentially get two solar-electric systems for the price of one—saving up to $12,500 per system. Recalling what it was like to be without clean drinking water and hot water for several weeks, the couple also decided to invest in a solar hot water system for both residences that would provide some emergency water storage.



Neal-Clifford Solar Hot Water System

The solar storage tank for the SHW system uses an internal heat exchanger.

Energy savings through net metering aside, Philip figured that the tax credits and depreciation on the rental property maintenance and improvements would put thousands back in their pockets over the lifetime of the property and systems. With a tenant who was equally interested in energy independence and sustainability, there was nothing holding them back—except Louisiana's underdeveloped solar industry and the little matter of hurricanes.

Getting a Solar Start

For the installation of all three systems, Phillip hired Jeremie Branton of Freedom Power, the first state-licensed installer in Louisiana. While waiting for the delivery of the PV system components, Phillip and Jeremie focused on the solar hot water system since the components were readily available from a local distributor. Phillip chose a closed-loop system with a 120-gallon tank to provide ample hot water for both residences and limited water storage in the event of an emergency.

The biggest challenge with the installation was maneuvering the 400-pound solar storage tank into the attic. To provide a staging area for working with the tank, Phillip hired a carpenter to build a raised platform off the back of the house. A mechanical lift was then used to raise the tank

Two backup water heaters, one on-demand and one tankless, provide supplemental water heating for each residence.

Solar Hot Water Tech Specs

Overview

System type: Active closed-loop

Production: 784,000 Btu per month (average)

Percentage of hot water produced annually: 80% (serves both residences)

Equipment

Collectors: Two Chromagen SLCR32, 4 x 8 ft.

Collector installation: Roof-mounted on south-facing roof, 24° tilt

Heat-transfer fluid: Dowfrost HD

Circulation pump: Taco 009

Pump controller: Goldline GL-30

Storage

Tank: Rheem, Solaraide HE, 120 gal.

Heat exchanger: Integral

Backup DHW: Electric (one on-demand; one tank-style per residence)

to the platform, where it was turned on its side, slid into the attic, maneuvered behind the chimney, and then righted into position.

While Phillip admits that it would have been easier to locate the tank in an existing shed on the lot, he decided to place the tank in the attic to keep it well above flood level and to maximize efficiency by placing it as close as possible to the collectors. The attic location also made it easier to feed hot water to both residences. He also installed a manifold so the solar hot water tank could feed the two residences separately—a necessary measure to ensure that some of the up-front costs for the SHW system could be depreciated for tax purposes. Phillip outfitted each residence with its own on-demand electric water heater, purchased at half-price with a discount for Hurricane Katrina victims, and a 6-gallon, electric tank-style heater.

Two 4- by 8-foot Chromagen flat-plate collectors were mounted on the south-facing roof above the rear porch. “Since no collectors are shown to survive better or worse in hurricane or high-wind conditions, all you can do is secure the collectors and hope for the best,” Jeremie says. “The collectors are in a good spot, but it’s not any more or less prone to wind damage.”

PV System Solutions

Armed with an associate’s degree in building science and years of hands-on experience with electrical wiring, Phillip took the lead on design and provided Jeremie with all the specifications for the solar-electric systems. The real challenge was to find a system that could withstand hurricane conditions. Again, Phillip turned to FSEC for advice. “Florida deals with weather patterns similar to those in Louisiana, so it seemed safe to say that whatever was doing the trick there would probably work well here,” Phillip says. “At the time, there were only a few PV installers in Louisiana, and the local resources just weren’t there yet—there was no one to hold my hand or walk me through the process.”

His research led him to Uni-Solar photovoltaic laminates (PVLs)—flexible, lightweight modules that are certified for winds up to 146 mph. Phillip read numerous stories of PVLs being used in residential and commercial applications along the Gulf Coast and learned that it was approved by Miami-Dade County, Florida, as “hurricane resistant.” Because the modules could be applied directly to the metal roof with a peel-and-stick adhesive, there was no mounting rack for hurricane winds to get under. On the downside, no racking meant that the modules’ tilt could not be adjusted and that the angle of incidence would be set by the roof’s pitch.

While these modules were chosen specifically for high-wind resistance, the Uni-Solar laminates have other attributes that work well for this installation. Made with triple-junction thin-film amorphous silicon cells, they should capture a wider spectrum of light for improved power production in overcast skies. Additionally, these modules perform better under high-temperature conditions. Finally, since these glassless modules are shatter-resistant, flying debris stirred up by hurricane winds will not pose as great a threat. On the flip side, amorphous thin-film modules are about half as efficient as crystalline modules, requiring about twice as much room to produce the same amount of energy.

Adhered directly to standing-seam metal roofs and certified to withstand 146 mph winds, laminate PV is a good choice for hurricane-prone regions.

Phillip wanted both systems to be grid-tied, which enables each residence to sell excess PV-generated power to the utility. It was also important to have enough battery backup to provide power for critical loads for both residences—refrigeration, lights, and one electrical outlet per residence for powering a computer or television—should the grid become unavailable.

PV System Specifics

The original plan called for 42 136-watt modules to be installed on the southeast-facing roof. Only when Jeremie climbed on the roof to begin the installation did he realize that the actual roof dimensions differed from those indicated on Phillip's design—the ridge-to-eave distance was not 20 but rather 16 feet.

Forced to reconfigure the system design, Phillip and Jeremie decided to install 42 68-watt modules on the house's southeast-facing roof and 21 136-watt modules on the nearly flat north-facing roof on the shed. That meant returning half of the PVL-136s to the distributor and waiting three months for the PVL-68s to be delivered.

Having never worked with laminates, Jeremie says he faced a steep learning curve. The key challenges, he says,

(continued on page 66)

PV System Tech Specs

Overview: House System Only

System type: Grid-tie solar-electric with battery backup

System location: New Orleans, Louisiana

Solar resource: 5 average daily peak sun-hours

Production: 250 AC KWH per month (estimate by NREL PVWatts)

Utility electricity offset: 35%

Photovoltaic Array

Modules: 21 Uni-Solar PVL-136, 136 W STC, 33 Vmp, 24 VDC nominal

Array: Seven three-module series strings, 2,856 W STC total, 99 Vmp, 72 VDC nominal

Array combiner box: OutBack PV8 with seven 8 A breakers

Array disconnect: E-Panel, 60 A DC breaker

Array installation: Installed on north-facing roof at 5° tilt

Energy Storage

Batteries: Eight Deka 8G31DT-DEKA, 12 VDC nominal, 97.6 Ah at 20-hour rate, sealed gel

Battery bank: Two four-battery strings, 48 VDC nominal, 195.2 Ah total

Battery/inverter disconnect: 125 A breaker

Balance of System

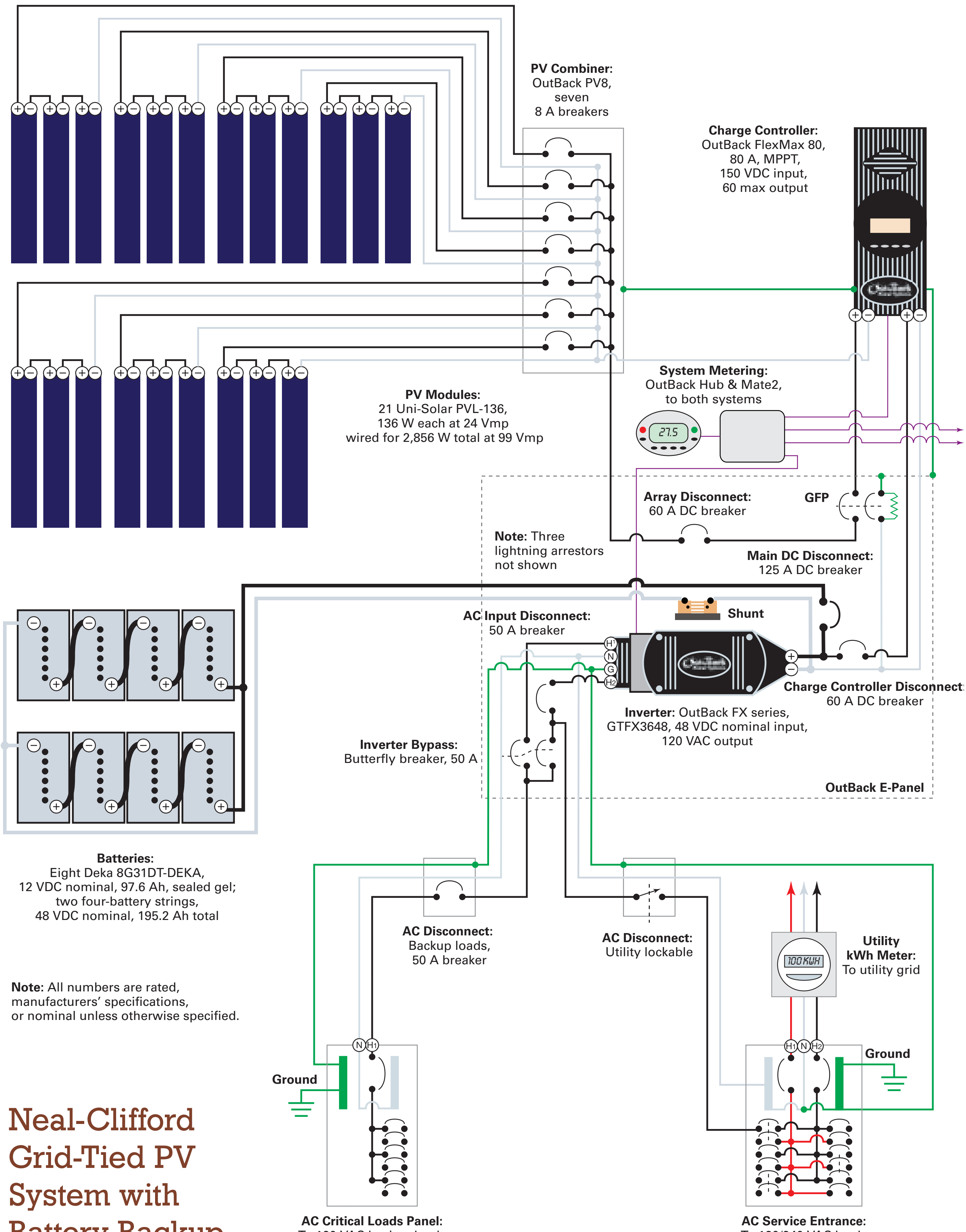
Charge controller: OutBack Flexmax 80, 80 A, MPPT*, 150 VDC max Voc input voltage; 12, 24, 36, 48, or 60 nominal output voltage

Inverter: OutBack FX series, GTFX3648, 48 VDC nominal input, 120 VAC output

System performance metering: OutBack MATE2, bidirectional utility kWh meter

*When corrected for the site's historical low temperature of 7°F, the array maximum system voltage could exceed the charge controller's 150 VDC maximum voltage rating, damaging the controller and voiding the product's warranty. String sizing should always account for both historical low and average high temperatures.

Neal-Clifford Grid-Tied PV System with Battery Backup



Left: The main house system, with its balance of system components in the shed.

Right: The second system houses the BOS components in weatherproof wall-mounted boxes.

came from applying the modules to the roof—a process that took more than two weeks. First, a toe-board system—fashioned from 2 by 4s and beam clamps—was put in place for fall protection on the sloped roof. The roof had to be cleaned with a solution of trisodium phosphate and laundry detergent, and then wiped down top to bottom with rubbing alcohol. After applying the first couple of laminates, Jeremie found that some of the adhesive had left unsightly black scuffs on the standing seams. Because the 16-inch-wide laminates fit almost perfectly between each standing seam, there was little room for error. To protect the seams, Jeremie ended up covering each with painter's tape before applying the laminates.

The weather also proved challenging. In hot weather, the adhesive protection would not easily peel off the back of the module. And cold temperatures made the modules stiff and difficult to unroll. Rain shut down the operation for a few days. A moveable tarp was used for rain and heat protection, and the modules were stored in a conditioned space until they were ready to install.

The laminates for the tenant's system were applied to the southeast-facing portion of the home's roof, which is pitched at 30°. The main residence's PV array was applied to the low-pitched (5°) north-facing roof on the shed behind the house. Energy production losses due to non-optimal orientations are estimated at 4% and 12% respectively.

Once all of the modules were in place, the roof's ridge cap had to be replaced—the original cap would not cover the wiring adequately. Each array was then wired into its own combiner box, maximum power point tracking charge controller, battery bank, and inverter, and operates completely independently. The systems use OutBack inverters

Right: Laminates typically offer better performance in situations where partial shading occurs. Each PV module is one long cell with a bypass diode, which makes it difficult to completely cut off a cell's production.

Below: The utility service entrance, with PV systems' disconnects.

Battery Backup

The battery bank installed in the main PV system has eight 12 V, 97.6 Ah batteries. This system is not designed to run major loads—such as the home's air conditioner—during a power outage. But if the battery bank is cycled down to 20% state of charge (80% depth of discharge), it can provide about 6.7 kWh to the critical loads, assuming an inverter efficiency of 90%.

For example, during stormy weather, this could provide three days of backup for an energy-efficient refrigerator (1.2 kWh/day), plus a handful of compact fluorescent lights (5 x 15 W x 5 hrs./day = 375 Wh/day) and a TV (130 W x 5 hrs./day = 650 Wh/day). With sunny skies, their 2.8 kW PV (flat/north facing) system could increase the energy available by about 8.2 kWh per day.

and charge controllers mounted within customized MidNite Solar E-Panels. All components were installed between 4 and 10 feet above the ground to protect against floods. For the rental system, two metal boxes were mounted on the tenant's side of the house—one with the inverter and one with the battery bank. The inverter, battery bank, and the rest of the balance of system hardware for Phillip and Jan's system were located in their shed.

From start to finish, the project ended up spanning from December 2007 to September 2008. Unexpected setbacks, red tape, and shipment delays contributed to the prolonged timeline. And Phillip says that dealing with the local utility was no picnic. He says it took "days to make my way through Entergy Louisiana's 54-page packet," which included a 14-page application and a 40-page contract for net metering.

"There's no denying that we're a state loyal to our oil and natural gas roots, so it is far from surprising that the utility did not go out of its way to streamline the process," Phillip says.

Living with Solar

Phillip continues to work with Entergy Louisiana to clarify the billing/crediting process of the battery-backup, grid-connected PV system. Until the utility works out the kinks with its digital meters, the best gauge of the systems' performance comes from the solar kWh production totals on the charge controllers.

While it is too soon to know if the actual output of each system will reach the design goals of 250 kWh per month and 273 kWh per month, so far Phillip's PV array energy production averages 9 kWh per day, and the system installed on the rental property averages 10 kWh per day. This slight difference is due to the rental property system's better orientation and tilt angle. Because energy measurements were taken on the DC side of each system at the charge controller(s), inverter efficiency has not been accounted for, so actual AC kWh production is slightly lower (estimated to be about 9% lower, using the weighted efficiency of the GTFX3648 inverter).

Even still, Phillip and Jan are quite pleased. Their rebate check is on its way and their home is better equipped to handle an emergency. The icing on the cake is that all three systems held up just fine against the 110 mph winds of Hurricane Gustav last September. And the battery banks provided enough power for both residences to maintain critical loads for the few days that the grid was down. The couple's tenant, who chose not to evacuate, was even able to operate the lights, television, refrigerator, and computer during the storm.

Even with all three systems up and running, Phillip is still figuring out ways to protect his solar investment—even going so far as trying to buy the neighboring lot to ensure that no one can build a structure or plant a tree that will block his home's solar access.

It's an ironic twist for someone who not long ago depended on the oil industry for his livelihood. When Phillip, who holds an MFA from the University of Kentucky, was unable to find work as an art teacher, he ended up working as a draftsman for an oil company for much of his early career—following the footsteps of his father, who was a marsh buggy operator for an oil service company.

"I grew up respecting the oil industry because it put food on our table, and my Cajun background taught me to live off the land—so working for the oil companies never felt wrong," Phillip says, "But I regret the toll that the oil operations have taken on Louisiana and its environment, and that's why I am trying to do my part now."

Access

Home Power associate editor **Kelly Davidson** (kelly.davidson@homepower.com) recently moved to Takoma Park, Maryland—a nuclear-free zone since 1983.

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PV & SHW Systems Components:

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Deka • www.eastpenn-deka.com • Batteries

Goldline • www.goldlinecontrols.com • Pump controller

MidNite Solar • www.midnitesolar.com • Power panel for inverter, controller & breakers

OutBack Power Systems Inc. • www.outbackpower.com • Inverter, charge controller & combiner

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SOLAR Hot Water STORAGE

Residential Tanks with Integrated Heat Exchangers

by Brian Mehalic

A critical component of a solar thermal system is the storage tank—essentially a "Btu battery" where heat energy is stored. Storage allows the system to provide hot water at any time of day, whether the sun is shining or not, since solar production typically does not coincide with the peak periods of hot water demand, usually mornings and evenings.

The amount of storage needed depends on the number and habits of those using the hot water. For domestic solar hot water production, storage tanks usually range in size from 60 to 120 gallons. And since most people don't want to have to take cold showers during long, cloudy spells, tanks are commonly paired with a backup heat source, either electric or gas.

Integrated Heat Exchangers

There are numerous types of solar hot water systems but most use heat exchangers (see "Solar Hot Water Simplified" in *HP107* and "Solar Hot Water: A Primer" in *HP84*). Usually, and nearly always in climates with the potential for freezing, domestic/potable water does not go through the solar collector loop—instead, a heat transfer fluid (HTF), usually propylene glycol or distilled water, is used in a closed-loop solar circuit. The HTF is pumped through the collectors, where it picks up heat, and then flows through a heat exchanger, where that heat is transferred to the water stored in the tank. Often the heat exchanger is integrated into the storage tank, either as coils submerged in the water, or wrapped around and in contact with exterior of the tank wall (see "Fundamentals of Solar Heat Exchangers" in *HP128*).

The Rheem Solaraide tank is a direct backup tank with a built-in auxiliary heat source. Its wraparound heat exchanger is in direct contact with the outside of the tank wall, instead of being submerged in the tank.

Courtesy www.rheem.com

System Applicability

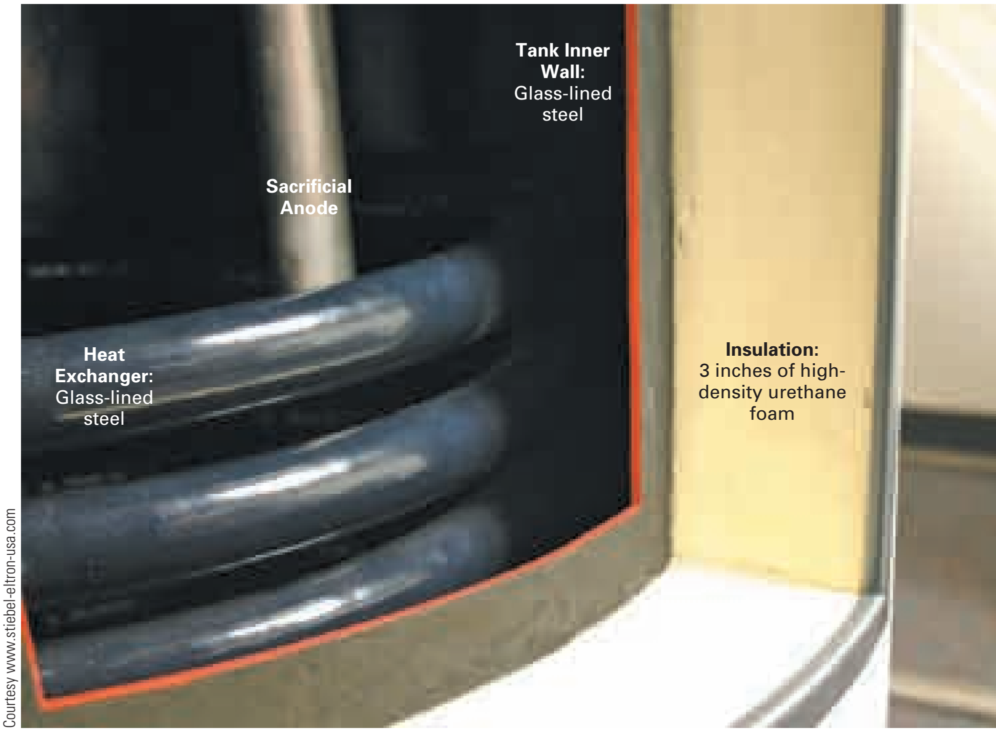
Storage tanks with integrated heat exchangers come in many varieties suitable for a range of applications. Many have an integrated backup heat source—typically one or more electric elements—or else have additional heat exchangers for a boiler or other external water heater.

These tanks are well suited for closed-loop glycol systems or, when paired with an external reservoir tank, for single-pump drainback systems. Additionally, they can function as a drainback tank, with the HTF filling the tank and fluid from a space-heating system circulating through the exchanger, picking up heat.

A Critical Distinction

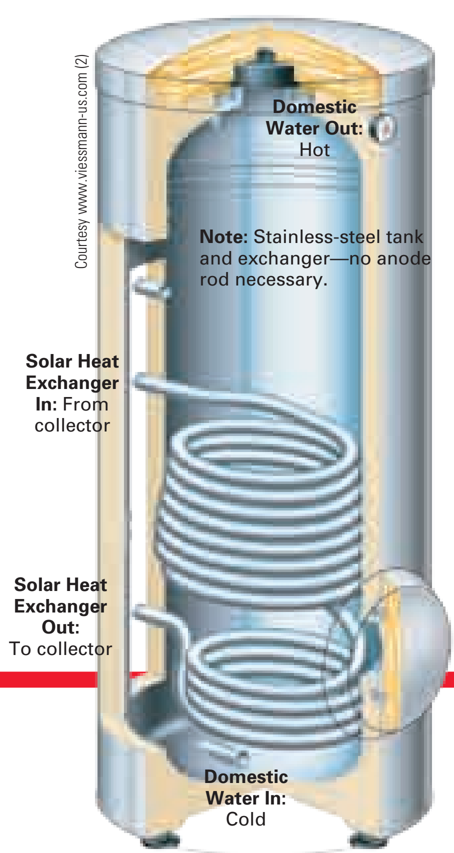
Heat exchangers are either single- or double-walled, and this is a very important factor in choosing the appropriate tank. A single-walled exchanger is typically a coil of pipe submerged in the tank, with only one thickness of pipe wall between the HTF and potable water. A double-wall exchanger adds a second layer of pipe to reduce the likelihood of contamination of potable water by the HTF. Double-wall exchangers will also often have airspace between the two walls. The airspace is typically filled with a thermally conductive paste but is not sealed—so if a leak occurs, fluid will accumulate and then drip out, providing a visual indication of the leak.

The 2006 Uniform Solar Energy Code requires the extra "layers" in a double-wall exchanger. Other plumbing codes are less clear, with some permitting



Courtesy www.stiebel-eltron-usa.com

A cutaway view of a Stiebel Eltron glass-lined tank with a submerged, glass-lined heat exchanger.



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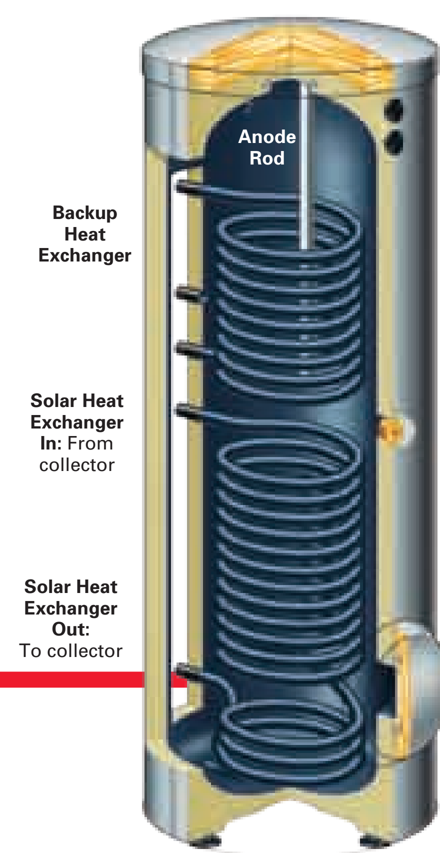


Left: This Veissmann storage-only tank has no integrated backup heat source.

Right: A Veissmann indirect backup tank with two heat exchangers: a lower unit for solar and an upper exchanger for backup.

single-wall exchangers when using HTFs that are generally recognized as nontoxic. Although propylene glycol is generally recognized as safe by the U.S. Food and Drug Administration and is used as a food additive, it is impossible to guarantee that the highly toxic and more readily available ethylene glycol (a common automotive antifreeze) won't be added to the system at some point. There have been many instances of old drainback systems being "serviced" and ending up with an unknown type of glycol in them. The codes used by your local jurisdiction will determine which type of exchanger you must use. Replumbing is no fun, and tanks are expensive, so contact your inspector and do your research before you buy.

Tank Types

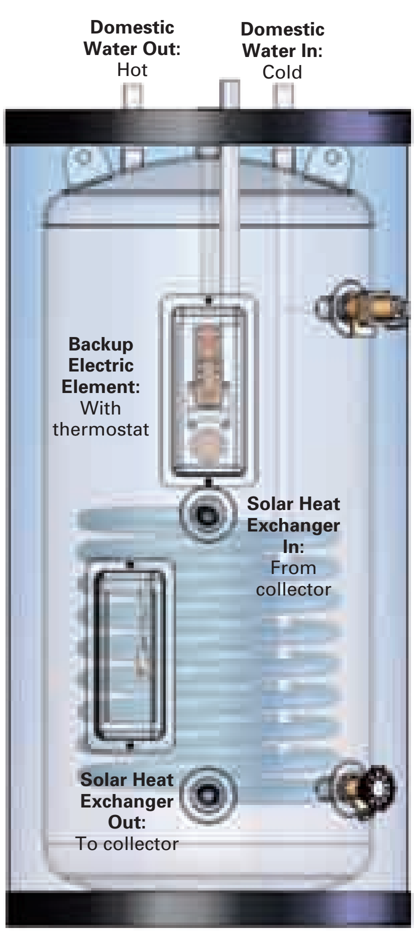
There are three main types of tanks with built-in heat exchangers: storage-only, indirect backup, and direct backup. Several models can fit into multiple categories.

Storage-only is the most basic type of integrated heat exchanger tank. Commonly referred to as indirectly heated, these tanks have a single heat exchanger—often a coil submerged in the lower half of the tank. Heated fluid—either from solar collectors, or in another common application, a boiler—passes through the heat exchanger and warms the water in the tank. When used in a solar thermal system, a backup source—either a second water heater tank or an instantaneous water heater capable of receiving preheated water—would be added (see "Sizing Solar Hot Water Systems" in *HP118*).

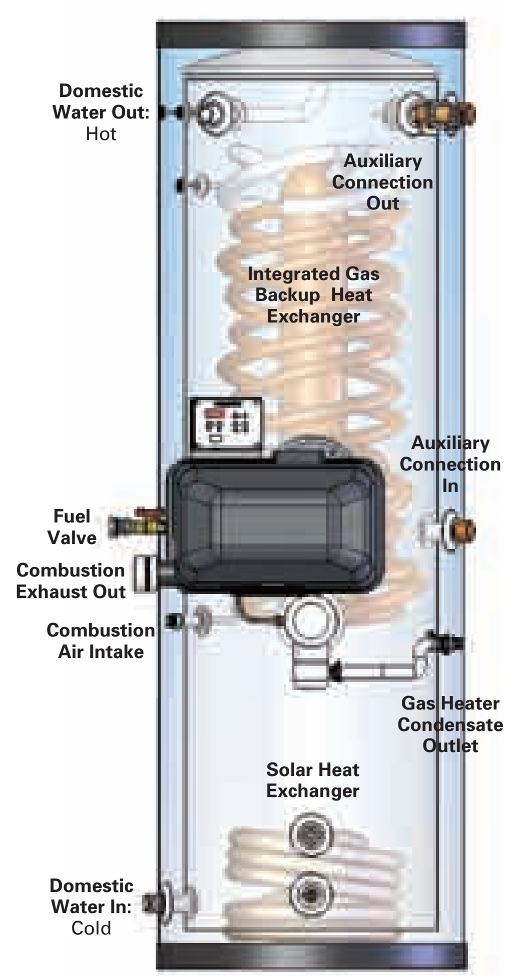
Indirect backup tanks have two heat exchangers: one in the bottom of the tank and another in the upper portion of the tank. The bottom exchanger is for the heated incoming solar fluid, while the upper heat exchanger introduces heat from a boiler or other backup source. As such, they are a popular choice for systems that already have a boiler for space heating. The second, upper coil can also be plumbed differently and utilized in other ways: instead of receiving heat from a boiler, it can supply heat to a radiant floor loop, or to a recirculating loop to keep hot water always available at the tap. The upper loop could also be used as a heat dump, sending heat to an auxiliary load such as a hot tub, pool, or buried coil to prevent the tank from overheating during high-temperature, low-use periods. Additional pumps and controllers would be required for these configurations.

Direct backup tanks have an auxiliary heat source built into the tank, allowing them to function as single-tank systems (see "Single-Tank Solar Water Systems" in *HP124*). Most often the backup consists of one or two electric elements—though there is at least one model that combines an integrated exchanger with a gas backup system in a single tank.

Standard electric-only hot water tanks usually have two electric elements: one in the upper part of the tank and one in the lower—thereby increasing the amount of water that is heated directly. But many solar tanks with direct electric backup only have a single element, located in the upper third of the tank, which only heats 20 to 40 gallons of water. While a single element will use less electricity than a double-element tank, it will also provide less backup capacity and take longer to heat. This detail is sometimes overlooked until the user ends up taking a cold shower during a period of little sun, and should be a strong consideration if hot water use tends to be concentrated, such as multiple showers taken in succession. For systems with high demand, several tanks feature *multiple* backup options—either two electric elements or an electric element paired with a second heat exchanger loop for indirect boiler backup.



Left: A common submerged heat exchanger with direct electric element backup by Heat Transfer Products.



Right: Heat Transfer Products' Phoenix Ultra is a unique combination of a solar heat exchanger with integrated gas backup, and an auxiliary connection for air handlers or radiant heating.

Understanding the Tables

The solar thermal industry has experienced a renaissance in recent years. As was the case in the late 1970s and early 1980s, there are many manufacturers offering a wide range of components and prepackaged systems. If you want to design your own system, choosing from the range of tanks, collectors, and components available, you must have a thorough understanding of how these parts function and integrate.

Often, the type of tank will be dictated by other factors such as boilers or hot water tanks that are already in service; the availability of backup energy sources; and the type of freeze protection utilized in the solar loop. System demand also plays a key role in determining tank size, further narrowing the number of tanks to select from. Tanks are listed in the table by type (storage-only, indirect, and direct backup), and then by manufacturer and capacity. The specifications featured are current as of this writing, but it is always wise to verify specs with the manufacturer before purchasing.

Tank Material

Glass or enamel-coated steel is the most common tank material, both for solar tanks and hot water tanks in general. Most manufacturers have proprietary names and techniques for their coating processes, such as Vitraglas or Thermoglaze. Coated steel is the most economical tank material, but all coated surfaces have imperfections, which can worsen during shipping and handling. So all the glass- or enamel-lined tanks in the charts include sacrificial anode rods. These magnesium or aluminum rods are typically threaded into the tank from the top, and offer a surface that is more prone to corrosion by waterborne copper particulates than the wall of the tank. The anode will have to be disintegrated before the tank wall suffers any corrosion, and, depending on water quality, should be replaced every five to 10 years. (See "Extending Tank Life: Anode Rods" sidebar.)

Another popular—although expensive—option is stainless steel. Often approaching twice the cost of coated steel, stainless tanks come with a longer warranty, weigh a little less, and do not require anode rods because of their inherent resistance to corrosion and mineral buildup. Stainless tanks typically have higher maximum temperature ratings, and are considered to be hygienic, since the lack of pores or cracks discourages the buildup of microorganisms, which can occur in lined tanks that have suffered corrosion.

Stone-lined tanks are another time-tested choice, though perhaps currently less popular. The stone liner absorbs water and holds it as an inert, noncorrosive layer against the steel tank wall. The cost is comparable to other lined tanks, but tanks may weigh up to 1.5 times more than glass-lined tanks, potentially increasing shipping costs.

Another tank material, though not available on any of the tanks in the following charts, is polybutene or polybutylene, a type of plastic used to make seamless tanks that are impervious to rust and corrosion.

Extending Tank Life: Anode Rods

All coatings used on steel tanks have imperfections and they get worse from rough handling, like during shipping. Once water finds its way through the imperfections to the steel wall, corrosion begins. To resist corrosion, lined steel tanks (not stainless or titanium) benefit from the addition of a sacrificial anode rod. The anode rod gives any copper in the system (from home piping) the chance to attack it instead of the steel lining. Only after the anode rod has disintegrated does the copper go to work on the steel tank through the imperfections. Most anode rods are made of magnesium—which, depending on the water quality, may give water an unpleasant odor. In these situations, aluminum is typically substituted.

Anode rods all have life spans that are dependent on local water quality. In some cases, even with hard water, lined steel tanks last for 25 years. (Albuquerque is one place—my solar storage tank is 24 years old.) In other locations, their life span can be 10 to 15 years. Anode rod replacement every five to 10 years extends the life of any lined steel tank—perhaps indefinitely if the rod is always replaced before the previous one is completely gone.

—Chuck Marken

Heat Exchanger Specs

Note that the listed specifications are for the *solar* heat exchanger in the lower loop *only*, as it is the common component between the tank types. For indirect backup tanks with two heat exchangers, the second, *boiler* exchanger in the upper loop is usually the same size or slightly smaller. Manufacturers specify ratings for backup heat sources in Btu per hour.

The majority of heat exchangers are submerged coils, directly immersed in the lower section of the tank, and most of these are single-wall. Typically, exchangers with a higher surface area-to-volume ratio will perform better (assuming the total surface area is similar). This is not the case with double-wall exchangers, which usually have less volume at the same exterior dimensions, equaling a higher ratio, but are less efficient than comparably sized single-wall versions.

Wraparound exchangers that are not submerged, but are in contact with the exterior of the tank wall, are harder to compare, but their efficiency most closely approximates that of a submerged, double-wall exchanger.

System design is a significant factor in how efficiently any exchanger will perform—if the pump circulates too fast or too slow, the collectors will not be able to deliver their maximum heating capability. Likewise, if the collector-to-storage ratio is not properly sized, systems can overheat or, conversely, not reach a high enough temperature to prevent backup heaters from turning on.

(continued on page 78)

Solar Storage Tank Specifications:

Storage-Only

	Model	Tank Capacity (Gal.)	Tank Material	Heat Exchanger (Hx) Type	Hx Material	Hx Walls	Hx Volume (Gal.)	Hx Surface Area (Ft.2)	Hx Surface-to-Volume Ratio
Bradford White www.bradfordwhite.com	PowerStor SW-2-65-L	60	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	PowerStor SW-2-80-L	75	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	PowerStor SW-2-120-L	116	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	PowerStor 2 DW-2-65-L	64	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	PowerStor 2 DW-2-80-L	75	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	PowerStor SS RTV-75-L	75	Stainless	Submerged Coil	Stainless	Single	1.60	10.0	6.25
	PowerStor SS RTV-119-L	119	Stainless	Submerged Coil	Stainless	Single	4.60	21.3	4.63
Stiebel Eltron www.stiebel-eltron-usa.com	SB 150 S	39	Enamel	Submerged Coil	Enamel-Coated Steel	Single	1.90	12.1	6.37
	SB 200 S	52	Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.70	14.3	5.30
	SBB 300 S	81	Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.70	16.1	5.96
	SBB 400 S	109	Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.90	18.3	6.31
Viessmann www.viessmann-us.com	Vitocell-V 100 CVA-200	53	Ceraprotect Enamel	Submerged Coil	Enamel-Coated Steel	Single	1.45	10.8	7.45
	Vitocell-V 100 CVA-300	79	Ceraprotect Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.60	16.1	6.19
	Vitocell-V 100 CVA-450	125	Ceraprotect Enamel	Submerged Coil	Enamel-Coated Steel	Single	3.30	20.5	6.21
	Vitocell-V 300 EVI-200	53	Stainless	Submerged Coil	Stainless	Single	2.64	14.0	5.30
	Vitocell-V 300 EVI-300	79	Stainless	Submerged Coil	Stainless	Single	2.91	16.0	5.50
	Vitocell-V 300 EVI-450	125	Stainless	Submerged Coil	Stainless	Single	4.00	20.5	5.13

Indirect Backup

	Model	Tank Capacity (Gal.)	Tank Material	Heat Exchanger (Hx) Type	Hx Material	Hx Walls	Hx Volume (Gal.)	Hx Surface Area (Ft.2)	Hx Surface-to-Volume Ratio
Bradford White www.bradfordwhite.com	EcoStor S-DC-DW2-55R6SW	55	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	EcoStor S-DC-DW2-70R6SW	70	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	EcoStor S-DC-DW2-110R6SW	110	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	PowerStor SS RTV-75D-L	75	Stainless	Submerged Coil	Stainless	Single	1.15	7.6	6.61
Buderus www.buderussolar.net	Logalux SM300	77	Thermoglaze	Submerged Coil	Thermoglaze Steel	Single	2.00	13.0	6.50
	Logalux SM400	103	Thermoglaze	Submerged Coil	Thermoglaze Steel	Single	2.50	14.0	5.60
Heat Transfer Products www.htproducts.com	Superstor Contender SSC-50SB	50	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Superstor Contender SSC-80SB	80	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Superstor Contender SSC-119SB	119	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
Stiebel Eltron www.stiebel-eltron-usa.com	SBB 300 Plus	81	Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.70	16.1	5.30
	SBB 400 Plus	109	Enamel	Submerged Coil	Enamel-Coated Steel	Single	2.90	18.3	5.96
	SBB 600 Plus	163	Enamel	Submerged Coil	Enamel-Coated Steel	Single	3.50	26.9	7.69
Viessmann www.viessmann-us.com	Vitocell-B 100 CVB-300	79	Ceraprotect Enamel	Submerged Coil	Stainless	Single	2.60	16.1	6.19
	Vitocell-B 100 CVB-450	125	Ceraprotect Enamel	Submerged Coil	Stainless	Single	3.60	20.5	5.69
	Vitocell-B 300 EVB-300	79	Stainless	Submerged Coil	Stainless	Single	2.90	16.1	5.55
	Vitocell-B 300 EVB-450	125	Stainless	Submerged Coil	Stainless	Single	3.90	20.5	5.26

Storage-Only & Indirect Backup

# of Hx	Hx Max. Pressure & Temp.	Tank R-Value	Standby Losses (Btu/Day)	Backup Source	Water Connection (In.)	Hx Connection (In.)	Cold Water Inlet	Size Diam. x H (In.)	Weight (Lbs.)	Price	Warranty (Yrs.)	Made In
1	150 psi 240°F	R-16	9,613	—	3/4	1	Top	22 x 60	196	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 240°F	R-16	9,013	—	3/4	1	Top	24 x 60	224	Unstated	Life, Tank & Hx; 6 Parts	USA
1	150 psi 240°F	R-16	9,293	—	3/4	1	Top	29 x 64	355	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 240°F	R-16	8,973	—	3/4	3/4	Top	22 x 60	196	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 240°F	R-16	9,013	—	3/4	3/4	Top	24 x 60	224	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 240°F	R-16	7,510	—	3/4	3/4	Bottom	24 x 64	117	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 240°F	R-16	14,300	—	1 1/4	1	Bottom	31 x 60	315	Unstated	Life, Tank & Hx; 6, Parts	USA
1	150 psi 203°F	R-14	6,500	—	3/4	3/4	Bottom	21 x 51	190	$1,083	5, Unlimited	Slovakia
1	150 psi 203°F	R-14	4,434	—	3/4	3/4	Bottom	21 x 63	226	1,219	5, Unlimited	Slovakia
1	150 psi 203°F	R-14	6,500	—	1 In. Adapter	1 In. Adapter	Bottom	28 x 67	292	1,904	5, Unlimited	Germany
1	150 psi 203°F	R-14	7,500	—	1 In. Adapter	1 In. Adapter	Bottom	30 x 73	371	2,063	5, Unlimited	Germany
1	150 psi 230°F	R-10	5,800	—	3/4	1	Bottom	24 x 56	214	1,727	8, Unlimited	Germany
1	150 psi 230°F	R-10	7,500	—	1	1	Bottom	28 x 69	333	1,994	8, Unlimited	Germany
1	150 psi 230°F	R-10	9,600	—	1 1/4	1	Bottom	36 x 77	399	2,503	8, Unlimited	Germany
1	220 psi 392°F	R-18	5,500	—	1	1	Bottom	26 x 56	168	3,595	Residential Lifetime	Germany
1	220 psi 392°F	R-18	6,800	—	1	1	Bottom	28 x 70	220	5,197	Residential Lifetime	Germany
1	220 psi 392°F	R-18	9,200	—	1 1/4	1 1/4	Bottom	39 x 70	245	6,335	Residential Lifetime	Germany

# of Hx	Hx Max. Pressure & Temp.	Tank R-Value	Standby Losses (Btu/Day)	Backup Source	Water Connection (In.)	Hx Connection (In.)	Cold Water Inlet	Size Diam. x H (In.)	Weight (Lbs.)	Price	Warranty (Yrs.)	Made In
2	150 psi 250°F	R-16	12,117	2nd Hx (Boiler Loop)	3/4	1	Top	22 x 60	210	Unstated	6,Tank & Parts	USA
2	150 psi 250°F	R-16	12,618	2nd Hx (Boiler Loop)	3/4	1	Top	24 x 60	236	Unstated	6,Tank & Parts	USA
2	150 psi 250°F	R-16	15,422	2nd Hx (Boiler Loop)	3/4	1	Top	29 x 63	340	Unstated	6,Tank & Parts	USA
2	150 psi 240°F	R-16	7,511	2nd Hx (Boiler Loop)	3/4	3/4	Bottom	24 x 64	130	Unstated	Life, Tank & Hx; 6, Parts	USA
2	232 psi 320°F	R-12	7,200	2nd Hx (Boiler Loop)	C: 1 1/4, H: 1	1	Bottom	27 x 58	317	$2,200	Limited Lifetime	Germany
2	232 psi 320°F	R-14	9,600	2nd Hx (Boiler Loop)	C: 1 1/4, H: 1	1	Bottom	34 x 61	445	3,200	Limited Lifetime	Germany
2	150 psi 180°F	R-17	<5,007	2nd Hx (Boiler Loop)	3/4	1	Top	23 x 47	187	1,275	7, Limited	USA
2	150 psi 180°F	R-17	<8,011	2nd Hx (Boiler Loop)	1 1/2	1	Top	23 x 72	286	1,528	7, Limited	USA
2	150 psi 180°F	R-17	<11,917	2nd Hx (Boiler Loop)	1 1/2	1	Top	27 x 64	367	1,888	7, Limited	USA
2	150 psi 203°F	R-14	6,500	2nd Hx (Boiler Loop)	1 In. Adapter	1 In. Adapter	Bottom	28 x 67	339	2,177	5, Unlimited	Germany
2	150 psi 203°F	R-14	7,500	2nd Hx (Boiler Loop)	1 In. Adapter	1 In. Adapter	Bottom	30 x 73	412	2,360	5, Unlimited	Germany
2	150 psi 203°F	R-14	10,000	2nd Hx (Boiler Loop)	1 In. Adapter	1 In. Adapter	Bottom	37 x 69	544	3,636	5, Unlimited	Germany
2	150 psi 320°F	R-10	7,800	2nd Hx (Boiler Loop)	1	1	Bottom	28 x 69	352	2,836	8, Limited	Germany
2	150 psi 320°F	R-10	9,500	2nd Hx (Boiler Loop)	1 1/4	1	Bottom	36 x 77	452	4,159	8, Limited	Germany
2	220 psi 392°F	R-18	7,200	2nd Hx (Boiler Loop)	1	1	Bottom	28 x 70	251	5,532	Residential Lifetime	Germany
2	220 psi 392°F	R-18	9,200	2nd Hx (Boiler Loop)	1 1/4	1 1/4	Bottom	39 x 65	275	6,648	Residential Lifetime	Germany

Solar Storage Tank Specifications:

Direct Backup

Manufacturer	Model	Tank Capacity (Gal.)	Tank Material	Heat Exchanger (Hx) Type	Hx Material	Hx Walls	Hx Volume (Gal.)	Hx Surface Area (Ft.2)	Hx Surface-to-Volume Ratio
Bradford White www.bradfordwhite.com	EcoStor SC S-SW2-60R6DS	60	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	EcoStor SC S-SW2-75R6DS	75	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	EcoStor SC S-SW2-115R6DS	115	Vitraglas	Submerged Coil	Glass-Coated Steel	Single	2.50	14.2	5.68
	EcoStor SC S-DW2-60R6DS	60	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	EcoStor SC S-DW2-75R6DS	75	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
	EcoStor SC S-DW2-115R6DS	115	Vitraglas	Submerged Coil	Glass-Coated Steel	Double	2.50	14.2	5.68
Heat Transfer Products www.htproducts.com	Superstor Contender SSC-50SE	50	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Superstor Contender SSC-80SE	80	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Superstor Contender SSC-119SE	119	Enamel	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Phoenix Ultra PH-80S	80	Stainless	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
	Phoenix Ultra PH-119S	119	Stainless	Submerged Coil	Cupronickel	Single	2.00	15.0	7.50
Rheem www.rheem.com	Solaraide HE 81V80HE-1	80	Rheemglas	Wraparound	Copper	Double	2.20	3/4 In. x 120 Ft. Tank Contact	—
	Solaraide HE 81V120HE-1	120	Rheemglas	Wraparound	Copper	Double	2.20	3/4 In. x 120 Ft. Tank Contact	—
Thermomax / K-TAM www.solarthermal.com	Solar Super Tank SST 60	60	Stainless	Submerged Coil	Stainless	Either	1.36	7.9	5.61
	Solar Super Tank SST 80	80	Stainless	Submerged Coil	Stainless	Either	2.04	9.8	4.91
	Solar Super Tank SST 119	119	Stainless	Submerged Coil	Stainless	Either	2.04	9.8	4.91
Vaughn www.vaughncorp.com	S65SRWHX 2045	65	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	
	S80SRWHX 2045	80	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	
	S120SRWHX 204545	119	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	
	S65SRWHX 4045	65	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	
	S80SRWHX 4045	80	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	
	S120SRWHX 404545	119	Hydrastone	Flanged, Removable	Copper	Either	0.20	20 ft2, Submerged, Finned	

Multiple Backup

Manufacturer	Model	Tank Capacity (Gal.)	Tank Material	Heat Exchanger (Hx) Type	Hx Material	Hx Walls	Hx Volume (Gal.)	Hx Surface Area (Ft.2)	Hx Surface-to-Volume Ratio
Thermomax / K-TAM www.solarthermal.com	Solar Super Tank SST 60 DB	60	Stainless	Submerged Coil	Stainless	Either	1.36	7.9	5.61
	Solar Super Tank SST 80 DB	80	Stainless	Submerged Coil	Stainless	Either	2.04	9.8	4.91
	Solar Super Tank SST 119 DB	120	Stainless	Submerged Coil	Stainless	Either	2.04	9.8	4.91
	Solar Super Tank SST 119 TC	120	Stainless	Submerged Coil	Stainless	Either	2.72	17.7	6.54
	Solar Super Tank SST 80DB OG	80	Stainless	Submerged Coil	Stainless	Either	1.36	7.9	5.61
	Solar Super Tank SST 119DB OG	120	Stainless	Submerged Coil	Stainless	Either	2.72	13.1	4.85
Vaughn www.vaughncorp.com	S80SRWHX 4045TB	80	Hydrastone	Flanged, Removable	Finned Copper	Either	0.20	20 ft2, Submerged, Finned	
	S120SRWHX 404545TB	119	Hydrastone	Flanged, Removable	Finned Copper	Either	0.20	20 ft2, Submerged, Finned	

Direct Backup & Multiple Backup

# of Hx	Hx Max. Pressure & Temp.	Tank R-Value	Standby Losses (Btu/Day)	Backup Source	Water Connection (In.)	Hx Connection (In.)	Cold Water Inlet	Size Diam. x H (In.)	Weight (Lbs.)	Price	Warranty (Yrs.)	Made In
1	150 psi 250°F	R-16	13,218	1 or 2 4,500 W Electric	3/4	1	Top	22 x 60	210	Unstated	6	USA
1	150 psi 250°F	R-16	13,519	1 or 2 4,500 W Electric	3/4	1	Top	24 x 60	236	Unstated	6	USA
1	150 psi 250°F	R-16	16,123	1 or 2 4,500 W Electric	3/4	1	Top	29 x 63	340	Unstated	6	USA
1	150 psi 250°F	R-16	13,218	1 or 2 4,500 W Electric	3/4	1	Top	24 x 60	210	Unstated	6	USA
1	150 psi 250°F	R-16	13,519	1 or 2 4,500 W Electric	3/4	1	Top	24 x 60	236	Unstated	6	USA
1	150 psi 250°F	R-16	16,123	1 or 2 4,500 W Electric	3/4	1	Top	29 x 63	340	Unstated	6	USA
1	150 psi 180°F	R-17	<5,007	4,500 W Electric	3/4	1	Top	23 x 47	175	$1,097	7, Limited	USA
1	150 psi 180°F	R-17	<8,077	4,500 W Electric	1 1/2	1	Top	23 x 72	237	1,350	7, Limited	USA
1	150 psi 180°F	R-17	<11,917	4,500 W Electric	1 1/2	1	Top	27 x 64	336	1,711	7, Limited	USA
1	150 psi 180°F	R-17	<8,011	130 KBtu or 199 KBtu Gas	1 1/2	1	Bottom	36 x 72	245	5,512–6,229	7, Limited	USA
1	150 psi 180°F	R-17	<11,917	130 KBtu or 199 KBtu Gas	1 1/2	1	Bottom	40 x 74	415	5,967–6,670	7, Limited	USA
1	150 psi 185°F	R-17	6,600	4,500 W Electric	3/4	3/4	Top	25 x 59	222	Unstated	6	Mexico
1	150 psi 185°F	R-17	7,800	4,500 W Electric	3/4	3/4	Top	29 x 62	380	Unstated	6	Mexico
1	150 psi 175°F	R-18	<12,017	1-In. Electric Port	3/4	1	Bottom	27 x 66	200	2,739	10	Canada
1	150 psi 175°F	R-18	<16,022	1-In. Electric Port	1	1 1/4	Bottom	27 x 77	230	3,231	10	Canada
1	150 psi 175°F	R-18	<23,833	1-In. Electric Port	1 1/4	1 1/4	Bottom	33 x 77	360	4,113	10	Canada
1	500 psi 180°F	R-16	<4,296	4,500 W Electric	3/4	3/4	Bottom	26 x 47	271	1,600	7	USA
1	500 psi 180°F	R-16	<5,287	4,500 W Electric	3/4	3/4	Bottom	26 x 58	321	1,800	7	USA
1	500 psi 180°F	R-16	<7,865	2 4,500 W Electric	3/4	3/4	Bottom	28 x 68	408	2,200	7	USA
2 Lower	500 psi 180°F	R-16	<4,296	4,500 W Electric	3/4	3/4	Bottom	26 x 47	271	2,400	5	USA
2 Lower	500 psi 180°F	R-16	<5,287	4,500 W Electric	3/4	3/4	Bottom	26 x 58	321	2,600	5	USA
2 Lower	500 psi 180°F	R-16	<7,865	2 4,500 W Electric	3/4	3/4	Bottom	28 x 68	408	3,200	5	USA

# of Hx	Hx Max. Pressure & Temp.	Tank R-Value	Standby Losses (Btu/Day)	Backup Source	Water Connection (In.)	Hx Connection (In.)	Cold Water Inlet	Size Diam. x H (In.)	Weight (Lbs.)	Price	Warranty (Yrs.)	Made In
2	150 psi 175°F	R-18	<12,016	2nd Hx + 1-in. Electric Port	3/4	1	Bottom	27 x 66	194	$3,167	10	Canada
2	150 psi 175°F	R-18	<16,022	2nd Hx + 1-in. Electric Port	1	1 1/4	Bottom	27 x 77	215	3,589	10	Canada
2	150 psi 175°F	R-18	<24,034	2nd Hx + 1-in. Electric Port	1 1/4	1 1/4	Bottom	33 x 77	380	4,677	10	Canada
3	150 psi 175°F	R-18	<24,034	2 Hx + 2, 1-in. Electric Ports	1 1/4	1 1/4	Bottom	33 x 77	380	5,634	10	Canada
2	150 psi 175°F	R-18	<16,022	2nd Hx + 2, 1-in. Electric Ports	1 1/4	1	Bottom	27 x 77	260	4,113	10	Canada
2	150 psi 175°F	R-18	<24,034	2nd Hx + 2, 1-in. Electric Ports	1 1/4	1 1/4	Bottom	33 x 77	360	5,106	10	Canada
2	500 psi 180°F	R-16	<5,287	2nd Hx + 4,500 W Electric	3/4	3/4	Bottom	26 x 58	321	2,800	5	USA
2	500 psi 180°F	R-16	<7,865	2nd Hx + 2 4,500 W Electric	3/4	3/4	Bottom	28 x 68	408	3,400	5	USA

A glass-coated heat exchanger coil by Bradford White.

Maximum Pressure & Temperature

Nearly all tanks are tested to at least 300 psi and rated for 150 psi working pressure on the water side. The temperature and pressure-relief valve (required both by code and manufacturer's instructions) offers protection against the tank overheating or exceeding its working pressure rating. Ratings for heat exchangers have a much wider range, with some models capable of withstanding significantly higher pressures and temperatures. In high-temperature conditions, glycol systems often need to circulate the heat-transfer fluid to avoid stagnation and overheating.

Insulation R-Value, Standby Losses

Once you've captured the solar energy in the tank, you immediately begin to lose it through the tank walls—eventually triggering backup heating systems. Most of the tanks listed here are well-insulated; those that lose fewer Btu per day are better insulated. Manufacturers publish standby losses either in Btu per day or °F per hour. To facilitate comparison, all °F per hour loss figures have been converted to Btu per day.

Port Sizes & Location

Most of these tanks use standard-sized fittings, though some include adapters to transition from metric ports (particularly those manufactured abroad). Replacement adapters can be difficult to come by, so before beginning the installation, always verify that all the fittings listed on the tank installation guide are provided. Manufacturers may also supply additional fittings with their tanks, such as temperature and pressure-relief valves, dielectric unions, and thermowells for thermometers. These fittings are not listed in the table, but since they are often needed, their additional cost can be significant. Tank manufacturers provide schematics showing what fittings are required, as well as a listing of what is included with the tank.

High demand/flow systems can require pipe sizes larger than the typical 3/4 inch, and many of these tanks do have larger connections on both the water and heat exchanger ports. However, you may end up using quite a few copper reducer bushings and spending extra time if everything is plumbed in 3/4 inch, and your tank comes with larger ports.

Heat exchanger connections are normally located on the lower sidewall of the tank, with the input port (from collector) about midtank, in line with but above the output to the collector. If the tank has a second heat exchanger, its ports are usually on the same side as the solar exchanger ports. Many of these tanks have cold-supply connections located on or near the bottom of the tank, unlike the majority of non-solar tanks. Plan accordingly so you don't end up with a circuitous piping layout.

Size & Weight

Moving a 120-gallon tank with two heat exchangers is no easy task. Even empty, these larger tanks can weigh more than 300 pounds. Placing the tank is also the most likely time for damage to occur, so consider your lifting plan and space constraints carefully. When replacing an existing tank, remember that solar storage tanks are somewhat larger than standard tanks and may require more room.

Warranty

All warranties are not created equal, so read the fine print. Warranties differ for residential and commercial applications, and include specific requirements for code compliance and installation. Most offer repair or replacement for a defect, but warranties may be void if it is proven that the maximum pressure and/or temperature ratings were exceeded. In some cases, the warranty is only valid for the original owner and cannot be transferred.

Access

Brian Mehalic (brian@solarenergy.org) is a NABCEP-certified PV installer, with experience designing, installing, and servicing PV, thermal, wind, and water-pumping systems. He instructs and develops curricula for Solar Energy International and lives in Prescott, Arizona.

Further Reading:

"Solar Hot Water: A Primer," by Ken Olson, *HP84*
"Solar Hot Water Simplified," by John Patterson, *HP107*
"Sizing Solar Hot Water Systems," by Carl Bickford, *HP118*
"Simplifying Solar Thermal," by Dan Gretsch, *HP124*
"Single-Tank Solar Water Systems," by John Patterson, *HP124*
"Solar Water Heating Systems Buyer's Guide," by Chuck Marken, *HP125*
"Fundamentals of Solar Heat Exchangers," by Chuck Marken, *HP128*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Money Matters:

Does an RE System Make Economic Sense?

by Dan Chiras & John Richter

In a recessionary economy where money can be a make-it-or-break-it variable for considering a renewable energy system, the burning question is: Does investing in a renewable energy system make economic sense?

The answer is rather nuanced and complex, but fear not—we will walk you through three methods of analyzing the economic costs and benefits of an RE system, giving you the tools to determine if an RE system fits your financial goals.

Preliminary Calculations

Step A:

Determine the average monthly electrical consumption of your home or business, preferably after incorporating conservation and efficiency measures. This figure can be calculated from past utility bills.

For example, we're going to assume that your super-efficient home in sunny southern Colorado requires an average of 420 kWh of electricity per month, or about 5,000 kWh per year or 13.7 kWh per day.

Step B:

Calculate the size of the system that will meet your needs—whether you want to offset all of your energy use or just a portion. A professional installer can perform this calculation, or you can do it yourself.

You've calculated your example daily electricity consumption: an average of 13.7 kWh. Now, you need to figure out how big your PV system needs to be, which is based on peak sun-hours. In this region, average daily peak sun-hours are 5.8. (Obtain average peak sun-hours for your site at http://rredc.nrel.gov/solar/pubs/redbook/.)

To size the system, divide the electrical demand (13.7 kWh per day) by the average daily peak sun-hours (5.8). This will give you an estimated system size—in this case, 2.36 kW. But you'll need to take efficiency losses into account. High temperatures, soiling, and equipment and wiring losses can shave about 30% off your array's rated output. After adjusting, you'll need a 3.4 kW system. For the sake of simplicity, let's assume that the system is installed in a shade-free location.

Step C:

Determine the cost of the system. Typical installed costs per rated watt range from $7 to $9, depending upon location and the complexity of the installation. For the most accurate pricing, get a bid from an RE professional.

Your local solar installer says the system can be installed for $8 per watt ($8 x 3,400 W = $27,200).

Step D:

Don't forget to account for financial incentives, which can shave off a significant amount from the bottom line. Visit the Database for State Incentives for Renewables & Efficiency Web site at www.dsireusa.org to see what's available in your location (see "RE Incentives" sidebar).

In our example scenario, the utility offers a rebate of $3.50 per watt of the installed capacity ($3.50 x 3,400 watts = $11, 900)—bringing the system cost to $15,300. Assuming you have a large enough federal tax liability to warrant it, you'll also receive a 30% tax credit from the feds (0.3 x $15,300 = $4,590). After subtracting all available incentives, the total system cost is $10,710 ($27,200 - $11,900 - $4,590 = $10,710).

Step E:

Calculate the output of the system over its expected lifespan—typically 20-plus years for a wind system and 30-plus years for a PV or solar hot water system. Multiply the lifespan by the kWh figure used to calculate Step B.

5,000 kWh/year x 30 years = 150,000 kWh

Method 1: Cost of Energy Comparison

One of the simplest ways to analyze a renewable energy system's economic performance is to compare the cost of energy produced by the system to the cost of electricity from the local utility.

Step 1:

Estimate the cost of RE-generated energy in kilowatt-hours (for solar- or wind-electric systems) or in therms (for solar hot water systems) by dividing the total cost of the system by the total output.

From Step E, we know that our example system will produce about 150,000 kWh over its lifetime. To calculate the cost per kilowatt-hour, divide the system cost ($10,710) by the output (150,000 kWh). In this case, your electricity will cost about 7 cents per kWh.

Step 2:

Compare the cost-per-unit energy generated by the system over its lifetime to the cost of energy from the local utility.

Considering that the going electric rate in Colorado is currently about 9.5 cents per kWh (including all fees and taxes), the PV system is a decent investment.

RE Incentives

Before calculating the cost of electricity from an RE system, be sure to subtract financial incentives from state and local governments, as well as local utilities. In Wisconsin, for example, more than 30 utilities participate in a statewide program called Focus on Energy, which rebates customers 25% of a PV system's cost, with a maximum rebate of $35,000. Similar programs are available in several states—visit the Database of State Incentives for Renewables & Efficiency at www.dsireusa.org to see what's available nationally and in your area.

For systems under 10 kW, the federal government offers a 30% tax credit to homeowners and businesses with no cap. The feds also permit businesses to depreciate solar-electric systems on an accelerated schedule, which means this investment can be recouped more quickly.

The U.S. Department of Agriculture also offers grants to subsidize the cost of renewable energy systems on farms and rural businesses in areas with populations less than 50,000. Grants cover 25% of the cost of the system, including installation. Their minimum grant is $2,500 (for a $10,000 system) and their maximum is $500,000. To learn more about the USDA grant program, visit www.rurdev.usda.gov.

Nationwide, electricity rates have increased an average of 4.4% per year over the past 35 years—twice that rate in some parts of the country. It's a fairly safe assumption that the rising cost of utility electricity will offset the interest paid for a loan or interest lost from the outright purchase of a renewable energy system.

Line Extension Fees

When comparing the cost of an off-grid PV system on a new home to the cost of electricity from the grid, don't forget to add line extension fees when calculating the lifetime cost of utility power. Line extension fees are the cost of connecting the home to already-existing utility wires. If your home or business is more than a few tenths of a mile from existing electric lines, you could be charged expensive line extension fees (up to $60,000 per mile in mountainous regions, according to the U.S. Department of Energy). Keep in mind that this only buys the installation of poles and electric lines. It does not buy you a single kilowatt-hour of electricity!

Variables

The cost-of-electricity comparison does not take into account a few key economic factors, such as interest on any money borrowed to purchase the PV system, which increases the per kilowatt-hour cost of PV-produced electricity. For those who purchase without borrowing, this economic analysis does not factor in lost opportunity value (i.e., lost potential income from interest the money could have been earning).

On the other side of the ledger, this analysis does not factor in the rising cost of electricity. Nationwide, electricity rates have increased an average of 4.4% per year over the past 35 years—twice that rate in some parts of the country. It's a fairly safe assumption that the rising cost of utility electricity will offset the interest paid for a loan or interest lost from the outright purchase of a system.

Method 2: Estimate of Return on Investment

Another fairly simple method that can be used to analyze the relative value of a PV or wind system is known as simple return on investment (ROI)—the savings generated by installing a renewable energy system expressed as a percentage of the cost.

Simple ROI is calculated by dividing the RE system's cost into the value of one year's worth of utility energy that the system offset.

For instance, a PV system that produces 5,000 kWh of electricity per year at the utility's rate of 9.5 cents per kWh generates $475 worth of electricity each year. If the system net cost is $10,710, the simple ROI is 4.4% ($475 / $10,710 = 0.044). If the utility charges 15 cents per kWh, the 5,000 kWh of electricity would be worth $750 and the simple ROI would be 7.0% ($750 / $10,710 = 0.070). Compare this to the March 2009 yields for 30-year treasury bonds at about 3.5%. Even in good economic times, these are respectable ROIs.

Variables

Simple ROI does not take into account interest payments on loans required to purchase the system or lost income opportunity if the system is paid for in cash. It also fails to consider the costs of maintenance, insurance, or property taxes. All of these factors decrease ROI.

This method also does not account for the gains on the other side of the ledger—the rising cost of electricity, for example. It also doesn't consider that money saved on the utility bill represents tax-free income, it does not factor in possible income tax benefits for businesses, such as accelerated depreciation, and it does not factor in increased home values. All these factors increase the value of the investment.

Despite these shortcomings, simple ROI is a convenient tool for evaluating the economic performance of an RE system.

Simple ROI is calculated by dividing the RE system's cost into the value of one year's worth of utility energy that the system offset.

Do avid anglers ever calculate the payback on their new bass boats? ($25,000 plus the cost of fuel and transportation to and from favorite fishing spots, divided by the total number of pounds of edible bass meat at $5 per pound over the lifetime of the boat.)

The Pitfalls of Payback

Simple payback is a term that came into use in the 1970s by well-meaning advocates of renewable energy and energy efficiency—and it's still in widespread use. Payback is the number of years it takes an RE system or an energy-efficiency measure to offset its cost through the savings generated.

Payback is calculated by dividing a system's cost by the anticipated annual savings. If the $10,710 PV system used in the previous examples produces 5,000 kWh per year and grid power costs 9.5 cents per kWh, the annual savings of $475 yields a payback of 22.5 years ($10,710 / $475 = 22.5 years). Using simple payback, this system will take almost 23 years to pay for itself. From that point on, the system produces electricity for free. While a payback of nearly 23 years seems long, don't forget that the ROI on this system, calculated earlier, was 4.4%—a respectable rate of return on your investment.

Interestingly, simple payback and simple ROI are closely related metrics. In fact, ROI is the reciprocal of payback. That is, ROI = 1 ÷ payback. Thus, a PV system with a 10-year payback represents a 10% return on investment (ROI = 1 ÷ 10). A PV system with a 20-year payback represents a 5% ROI.

Besides being economically misleading, simple payback is a concept we rarely apply in our lives. Do avid anglers ever calculate the payback on their new bass boats? ($25,000 plus the cost of fuel and transportation to and from favorite fishing spots, divided by the total number of pounds of edible bass meat at $5 per pound over the lifetime of the boat.) Have you calculated the payback on your new kitchen cabinets, swimming pool, or other consumer items?

Although payback and ROI are related, ROI is a much more familiar concept. We receive interest on savings accounts and are paid a percentage on mutual funds and bonds—both of which are a return on our investment. An RE system also yields a return on our investment by avoiding paying the utility, so it can make sense to use ROI to assess its economic performance.

Method 3: Comparing Discounted Costs

Discounting is a more sophisticated method that considers numerous economic factors, such as maintenance costs, the rising cost of grid power, and the time value of money. This last measure takes into account that a dollar today has more spending power than a dollar tomorrow or any time in the future. Economists calculate this loss of value by applying a discount factor, which represents inflation and opportunity cost: the cost of lost economic opportunities by pursuing one investment path over another. An example is investing your money in a PV system instead of investing your money in the stock market.

Discounted Cost Comparison*

Year	Utility Electricity Cost	Utility Electricity Discounted Cost	PV System Cost	PV System Discounted Cost
0	$0	$0	$10,710	$10,710
1	475	461	0	0
2	496	467	0	0
3	518	474	0	0
4	540	480	0	0
5	564	487	0	0
6	589	493	0	0
7	615	500	0	0
8	642	507	0	0
9	670	514	0	0
10	700	521	0	0
11	731	528	0	0
12	763	535	0	0
13	796	542	0	0
14	831	550	0	0
15	868	557	0	0
16	906	565	0	0
17	946	572	0	0
18	988	580	0	0
19	1,031	588	0	0
20	1,076	596	3,200	1,772
21	1,124	604	0	0
22	1,173	612	0	0
23	1,225	621	0	0
24	1,279	629	0	0
25	1,335	638	0	0
26	1,394	646	0	0
27	1,455	655	0	0
28	1,519	664	0	0
29	1,586	673	0	0
30	1,656	682	0	0
Total	$28,492	$16,942	$13,910	$12,482

*Assumptions: 3% discount factor & 4.4% annual utility rate increases

This economic analysis can be performed by a spreadsheet like the one that was used to create the "Discount" table. You can download an active spreadsheet to do your own calculations from the Web Extras section at www.homepower.com. For simplicity, choose as your discount factor the highest interest rate on any debt you have, including your mortgage. If you have no debt, choose the highest investment interest rate you can get with a low-risk profile (which reflects the investment "risk" in an RE system). A 10-year government bond is a good choice; it currently yields almost 3%.

The first column under "Utility Electricity" projects the cost of utility electricity at an annual increase of 4.4%. Its adjacent column is the discounted cost of electricity from the utility—which takes into account inflation's effects on the rising cost of electricity. It reflects the value of the money you'd spend over a 30-year period in present-day dollars. As you can see, although you will have shelled out $28,492 to the utility company, the present value of that money is only $16,942.

The first column under "PV System" shows what system costs were incurred over the years—$27,200 minus incentives, or $10,710 to start. At 20 years, we added a $3,200 expense to replace the inverter—a commonly predicted cost. If you have additional costs, like a maintenance contract, you would add that cost into that column for each year. In this case, over a 30-year period, you will have invested $13,910 in your system (in present dollars). The last column shows the PV system's discounted cost, the present value of your expenditure, factoring in the discount factor of 3%.

The final step is to compare the discounted cost of the system ($12,482) to the discounted cost of electricity from the utility ($16,942). In this example, the present cost of the PV system is $4,460 less than the present cost of utility electricity.

If an RE system is cheaper than buying electricity, it makes economic sense. If it costs more, it doesn't. The greater the difference in the cost of the two systems, the more compelling the economic argument to install.

Do the Math, Make Your Decision

Comparisons based on the costs of energy, ROI, or net present value are vital to making a rational decision about an RE system. Beyond the measure of money, there are a multitude of other logical reasons to invest in a system, such as energy security, a cleaner environment, the satisfaction of producing your energy locally, and adding green energy to the grid. The bottom line is that the decision is yours, no matter what metric you use.

Access

Dan Chiras (danchiras@evergreeninstitute.org) is the founder and director of The Evergreen Institute, which offers workshops in residential solar electricity, wind, passive solar design, home energy efficiency, and green building at the Center for Renewable Energy and Green Building in east-central Missouri (www.evergreeninstitute.org).

John Richter (energyprophet@comcast.net) is the cofounder of the Institute for Sustainable Energy Education and former president of the Great Lakes RE Association (www.glrea.org). He was featured on the PBS special, *Michigan at Risk: Michigan's Green Energy Economy*.

PV Safety & Firefighting

by Matthew Paiss

Courtesy Craig Allyn Rose

Fire safety is typically the last thing people think of when planning their rooftop solar-electric system, but it quickly becomes a hot topic when a blaze ignites. Here's a look into the potential hazards of PV systems when a fire breaks out—and how to minimize risks to firefighters.

Why do firefighters climb up on the roof of a burning building? In a house fire, superheated smoke and gases (which can exceed 1,200°F) rise to the ceiling and then bank down back to the floor. Just one lungful of this smoke can kill. Cutting a hole in the highest point of the room allows the superheated gases and fire to rise out of the building, rapidly improving visibility as well as the survivability of the structure and those trapped inside. This also allows firefighters on the hose line to advance inside to locate the seat of the fire and any victims. This "vertical ventilation" has saved many lives and valuable property—besides actual rescue, this is one of a firefighter's primary responsibilities.

But the presence of rooftop-mounted PV arrays has made cutting through a roof more challenging. In the past, the fire service had plenty of room to ventilate where it is most effective—directly above the fire. With PV arrays now covering large areas of roofs, firefighters are limited in where they can cut and where they can exit the roof. Since the PV modules cannot be cut through, and moving them is time-consuming and potentially dangerous, rooftop PV systems pose some risks—mainly shock and trip hazards.

Most firefighters have had some education in electrical theory but usually employ the tactic of avoidance when it comes to electrical equipment. However, there are still

those who believe that anything is manageable if you can swing an axe hard and fast enough—clearly not the best approach when dealing with electricity. Most firefighters will just ventilate as close as they can to the high point of a room. If an array is in the way, they will move to where they can cut safely and rapidly. One problem is that most roof systems employ lightweight trusses, held together by lightweight metal gusset plates. With small fastening points, they can warp and pull out in fire conditions. These roofs are known as "20-minute roofs," meaning that firefighters have 20 minutes or less to get up, make the necessary cuts, and get down before the roof gives out. So, time is of the essence when navigating a hot roof with a PV system.

Fire Safety Steps

Assessing the Situation. One of the first things firefighters do at the scene is to take a "hot lap"—a quick walk around the building to see all sides and to locate the utility shutoffs. It is usually at this point that a PV system is noted if the array was not visible upon arrival. An inverter—often outside near the meter and service panel—also serves as a signpost. Likewise, if metal conduit is present in an attic, that's a red flag that a PV system may be present.

But there are some cases where obvious indicators of a PV system are not evident—such as in cases where the modules are integrated into the roof or the inverter is located indoors. Besides visual identification, a common way to note a PV system is to look at the labels on the main service panel, typically located on an exterior wall. The labeling may be on the outside or inside of the main panel. There should be a dedicated breaker for the inverter, labeled "solar inverter" or some variation. This breaker also may be in a subpanel inside the structure, but a label on the main service panel should always state that there is a second generating source onsite as well as identify the dedicated breaker for the inverter. New guidelines from the California Office of the State Fire Marshal advocate labeling along the PV array's DC conduit run as well.

Shutting Down the System. With any structure fire, shutting off all the circuit breakers at the main distribution panel, closing any gas mains, and notifying all on the scene that the utilities are secure is standard operating procedure. Shutting down a PV system is not as simple or straightforward.

With grid-direct systems, the first step is to disconnect the inverter, which happens automatically when the utility

Taking Solar-Electric Systems Seriously

California's Office of the State Fire Marshal has put together a PV task force to respond to safety concerns of the fire services—as well as concerns from the solar industry over limits and inconsistent regulations being imposed on installations. Last year, a final draft of installation guidelines was created. These guidelines address:

Marking: High-contrast, reflective, and consistent wording must be used on conduit, electrical panels, and disconnects.

Access, pathways, and smoke-ventilation space: Providing a 3-foot setback from the edges of the roofline from gutter to ridge will ensure that firefighters can get onto and off the roof rapidly, if necessary. There is also a recommendation to provide a 3-foot setback along the ridgeline for ventilation. This is a highly contentious area, given the value of that space to both the fire service and solar installers. Alternative means of compliance are being considered.

Conduit runs: Considering the common use of chain saws for vertical ventilation, conduit runs should be kept 10 inches below roof decking (when run in attic spaces) to minimize the chance of being cut into.

For additional information on the draft guidelines, visit www.osfm.fire.ca.gov/training/pdf/photovoltaics/solarphotovoltaicguideline.pdf

Key Safety Points for PV & Firefighting

- Daytime = Danger—the PV system will be energized whenever sunlight hits the modules.
- Nighttime = No hazard from the PV system, but be aware of potential battery bank dangers elsewhere on the premises.
- Ensure that all breakers at the main electrical service panel are shut off.
- When a PV system is identified, it is imperative that everyone on the fire ground be notified. Securing the main electrical panel does not shut down the PV modules. Voltage can continue in the wiring between the modules and the inverter in the daytime.
- Firefighter-supplied lighting, like high-lumen emergency lighting—called "scene lighting" in the fire service—will not produce enough light to generate dangerous voltage from the arrays.
- Sunlight can be blocked only by opaque material. Remember: All of the modules need to be covered for the array to be rendered inoperable.
- Stay away from the arrays and conduit. Don't break, remove, or walk on the modules.

power is shut off. Inverters also are designed with very good ground-fault interruption (GFI). If an inverter detects voltage between the ground and any of the metal conduit, the modules themselves, or the mounting racks, the inverter trips the GFI and opens the circuit. The circuit is also opened when the inverter is shut down manually by tripping the main circuit breakers either for just the inverter or for the whole house.

However, even with the inverter off, there's no easy way to shut off the high-voltage DC electricity flowing through the array and the DC wiring. In daylight when there is an open circuit, the modules are still putting out full voltage. There's no current flowing—that is, unless it finds a path to ground, like through a firefighter or an axe breaking through walls or ceilings.

The use of a rooftop disconnect at the array can lead to a false sense of security, since that merely opens one side of the circuit. Complicating matters is that many PV systems have more than one subarray—which can be located on another section of roof. These subarrays could backfeed power through the inverter or combiner into the conduit that was supposed to be de-energized by the rooftop disconnect. The concept of having both the line and load sides of a disconnect energized is a potentially dangerous situation in this application. For this reason, the California Office of the State Fire Marshal frowns upon the installation of rooftop disconnects.

Don't Forget!

Even though PV systems can produce high voltages, the AC line voltages that come into all structures can be much more dangerous. On a recent fire, I noticed that the utility service drop was within easy contact and the insulation on the wires was missing in some spots. Since this is on the utility side of the meter, the current would be unregulated up to the limits of the wire, which could be close to 1,000 amps—a serious electrocution hazard.

During daylight, there can be enough voltage and current to injure or even kill a firefighter who comes in contact with the energized conductors. A hanging conduit with wires sticking out of it is nothing out of the ordinary on the scene of a fire, so firefighters must exercise extreme caution when navigating a fire. It is best to always assume that a PV system is energized and steer clear of the modules and conduit. Here's an example: If a firefighter accidentally or deliberately axes through a string of twelve 44 VDC modules, he or she will experience a potentially deadly surge of 528 volts.

Off-grid and grid-connected systems with battery backup have a few more circuits to consider. First, PV array disconnects should be shut off. Second, the battery banks in these systems are another power source that need to be shut down via a main DC battery disconnect to fully de-energize the inverter and any AC circuit fed by the inverter, as well as any DC circuit that might be present. Like the PV array, battery banks are live even after they have been disconnected from the rest of the system. And even though most battery banks are wired to low DC voltages (commonly 24 V to 48 V), which pose less of a shock hazard than the high-voltage DC circuits discussed earlier, their low voltage and high current nature can cause fires from overheated connections. Batteries are also full of sulfuric acid and emit hydrogen gas that is highly flammable.

Battery banks are usually contained in a plastic, metal, or wooden storage box located near the system control panel—typically in the garage, basement, or shed. Battery banks also may be placed somewhere on the exterior of the house. If the heat and flames of the fire are near the battery bank, firefighters should use dry chemical or CO_2 extinguishers instead of water to avoid the potential for shock hazard of spraying a live inverter and to minimize damage to the batteries. That said, salvaging a battery pack is always secondary to firefighter safety and saving

(continued on page 92)

Bright, clearly labeled disconnects are important to firefighters on the scene.

Courtesy Matthew Paiss (2)

Courtesy Matthew Paiss

Firefighters cover a PV array with opaque tarps to cut off array power production.

Firefighting & Off-Grid PV Systems

Wildfire is a constant danger in many rural and remote areas, where off-grid PV systems are most common. Rural fire departments respond to both wildland and structure fires, ever mindful that each type of fire can quickly turn into the other. Federal, state, county, and other local wildland fire agencies often respond to all fires in their area as "mutual aid," depending on whose land is or might become involved. Unlike their counterparts in the suburbs and cities, wildland firefighters do not carry equipment to ventilate roofs or enter burning buildings, and usually do not have enough water or apparatus available to extinguish a burning building—their job is to prevent your home from igniting in the first place.

Prevention & Preparation

The more remote your area, the more responsibility you must take for fire prevention and preparation at your home. The time to prepare, though, is well before fire season—not when the sheriff drops by and tells you to leave within 15 minutes.

Keep your system clean and clear of flammable debris. Regularly remove any leaves, pine needles, or twigs caught between your PV modules and the roof. Firebrands can be carried by wind for long distances and can easily ignite such litter. If your PV array is on a ground-mounted rack, keep grass and brush trimmed underneath and around it.

Label all racks, combiner boxes, and conduit. Should burning debris land on your roof, firefighters may need to climb up there to extinguish it, and may not understand the electrical hazards from PV modules. Simple warning labels—such as "Caution: High-Voltage Solar-Electric System"—could help prevent personal injury as well as avoid damage to your system and home.

In an Emergency

Your ever-reliable off-grid system can help keep firefighters safer while they are protecting your off-grid home and give them a critical edge in saving your home from an approaching wildfire. The key: Leave your PV system on when you evacuate!

In remote areas with no fire hydrants, shuttling water in fire engines is a difficult problem. Prepare a sign in advance with details about your water—where it is, how much there is, and how to access it. Post the sign on your front door before you evacuate, and leave the porch light on to illuminate the sign and make your home visible to firefighters at night. Make sure all of your doors are unlocked—to your home, outbuildings, and water pumping control point.

Since your PV system has been left on, your domestic water pressure pump will be working. Connect garden hoses to outdoor faucets before you leave. If your well pump requires a generator to fill the cistern, then keep the generator gassed up, with instructions posted on how to pump from your well.

Also, keep in mind that "scene lighting" for a typical wildland fire crew consists of helmet headlamps and fire engine headlights. Your outdoor lighting could be very helpful for defending your home.

—Dan Fink

Courtesy Matthew Paiss

The author and his ground-mounted PV array.

the structure. However, when dealing with a minor fire or an overheated battery connection, firefighters should act prudently and do their best to avoid damaging thousands of dollars' worth of equipment.

Eliminating the Source. One option for shutting down a PV system is to cover the arrays with opaque material, such as heavy canvas tarps or black plastic. Most fire response vehicles carry some type of salvage covers or tarps that are commonly used to protect belongings from water damage during firefighting. These same tarps can also be used to prevent light from reaching the PV cells, shutting off the flow of electricity to the inverter. However, high winds, tarp sizes, structural conditions, and the size and shape of the array may prevent using this option. Some departments do not carry suitable tarps, and common blue poly tarps will not work because they let too much light through.

Dealing with Conduit. If the array cannot be tarped, it is important for the crews inside to be careful when opening holes in the ceiling, as they may contact the conduit from the array with their tools. Since plastic insulated wire (Romex) is all that's typically required for home wiring, metal conduit is rarely used in an attic spaces.

Firefighters must verify whether a metal conduit run is intact. If so, it is grounded from the array to the inverter, so any wires that may be shorted to it from the high heat of a fire will carry any voltage/current to ground rather than to the firefighter who contacts it. In other words, it is safe to touch. But if portions of the roof have collapsed, it should be assumed that the conduit is no longer grounded and therefore dangerous to touch. Most fire departments carry noncontact voltage detectors that can be used to find hot AC lines. Unfortunately, DC noncontact voltage detectors, which would alert firefighters to the presence of PV-generated electricity, are unavailable.

In a nighttime fire where the attic space was exposed to severe heat damage, the conduit and wires inside may have become compromised. Some arcing could begin as the rising sun energizes the modules the following morning—a potential for starting a new fire. A qualified solar contractor should be called in to disconnect the arrays. Unfortunately, most PV companies do not have an on-call technician available, so the disconnect usually must wait until the next day—not always the safest measure. In this case, most fire departments will post a "fire watch" until a qualified contractor can ensure the array is disconnected. Local utility companies are not responsible for the customer side (the house side of the meter) appliances and will not respond just to secure PV systems. This is where cooperation with the solar industry comes into play. The fire service recommends that all PV installers have an after-hours response contact for such emergency situations.

Keeping Safety in Mind

Identification is the key to understanding these systems and avoiding injury. Taking precautions with a PV array is one way to ensure the safety of firefighters and reduce the risks to your system. Beyond siting your system for optimal safety in the event of a fire, homeowners should consider installing interior fire sprinklers, which could be the critical difference between saving or salvaging your home and system. Invite your local fire department to tour your PV system if it's a rarity in your locale and provide them with a schematic of the system for their records. Further information about installing safe PV systems can be found in the California Office of the State Fire Marshal's draft guidelines.

Access

Fire engineer **Matthew Paiss** (mpaiss@earthlink.net) has been a member of the San Jose (California) Fire Department for 13 years. He teaches classes in PV safety, and has degrees in both fire science and solar technology. He has PV and solar thermal systems on his home.

Dan Fink (danbob@otherpower.com) has been a firefighter with the Rist Canyon (Colorado) Volunteer Fire Department for 10 years, and lives in a remote, completely off-grid corner of their response area. He is a writer and photographer for www.otherpower.com, with 16 years of experience in renewable energy system design, installation, and consulting.


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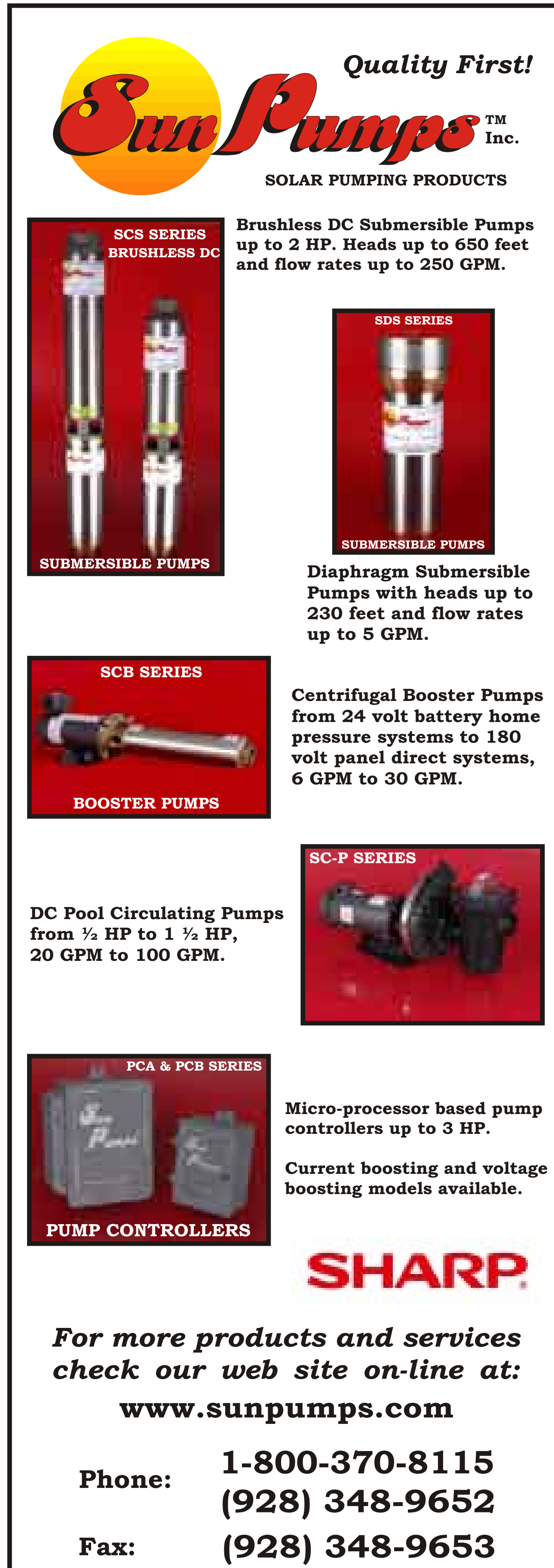
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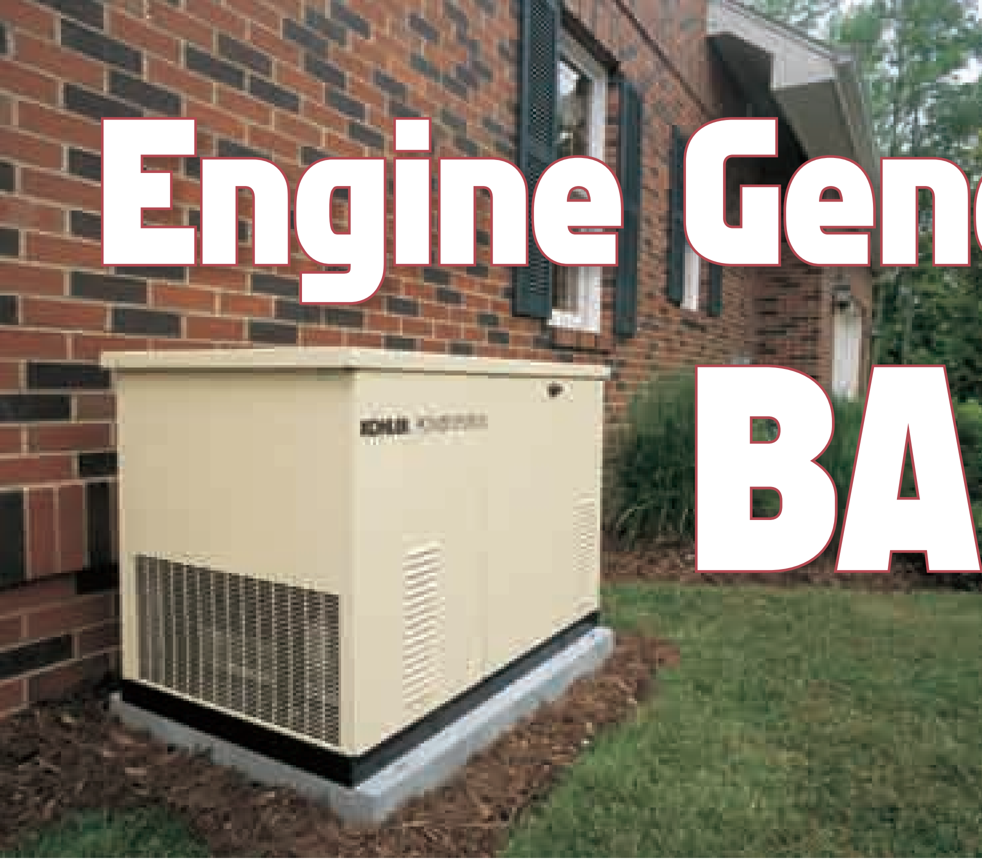

Engine Generator BASICS

by Allan Sindelar

Courtesy www.kohlerpower.com

Unless you have a good hydro or dependable wind source, or an excessively large PV system, sometimes the only way to keep your off-grid power system operating is by using an engine generator. But many residential generators are poorly matched to the job, since the selection and purchase of a generator is often an afterthought. The result is the generator becoming the weak link in the system, with inefficient, unreliable performance, rather than being an integral component of a well-functioning system. Here's how to analyze your generator needs and choose the right unit for the job.

Function & Purpose

Generators serve three main roles in off-grid home systems:

- The first is **backup charging,** where the generator makes up for any deficit in energy from the solar array or wind turbine, since the generator will work in any weather.
- The second function is **battery equalizing.** All flooded batteries need to be overcharged several times each year for best service life and performance. Equalizing is the deliberate overcharge of an already-full battery—raising the battery voltage to a higher-than-normal voltage (as specified by the battery manufacturer) and keeping it there for 2 to 3 hours. A minimum charge rate of about C/20 is necessary to overcome internal resistance to achieving such a high voltage (see "C-Rating" sidebar). Most off-grid PV arrays aren't powerful enough to accomplish this, especially during the winter, so a generator becomes an essential tool to achieve this.
- The third role is to **run specific loads that exceed the capacity of the inverter(s),** such as 240-volt deep-well pumps, stationary shop tools, and even air conditioners.

The Basics

"You get what you pay for" might as well have been coined by a generator owner. Even in a well-designed off-grid power system, the generator is likely to be the single greatest source of maintenance and aggravation. It's a mechanical device, rather than electrical, so it requires regular maintenance and *will* eventually break down—usually when it's most needed.

Ask yourself: Is a breakdown just an annoyance or will it completely disable my home's power system? The more serious the consequences of the inevitable breakdown, the greater the appeal of a top-quality commercial/industrial generator. Consider also that unless you are prepared to maintain and repair the machine yourself, you will need reliable local support when the eventual failure occurs. An investment in quality quickly pays off.

Generators for home use may be purchased for as little as $300 or as much as $12,000. The least-expensive units are designed for occasional homeowner use with power tools or

The rated output of this generator is the combined wattage of both 120 V legs. At most, half of that power is available at 120 V—full power is only available at 240 V.

Courtesy www.positiveenergysolar.com

cement mixers, for instance. “Contractor’s specials,” common at home-improvement centers, are just that—with their low initial cost, they are designed to provide temporary power until utilities are installed or to build a remote cabin. They’re designed to be worked hard and then written off as a business expense when they die.

For off-grid backup, your choice will constitute a compromise between application, cost, availability, and support. But a higher-quality unit will generally have the following features:

- **Electric start with two-wire remote start capability:** “Two-wire” means all starting control functions (such as cranking and crank duration) are handled within the generator, rather than externally. Remote start capability means that the start and stop signals can be sent from an inverter or other controller. (See “Automatic Generator Start” sidebar.)

- **No or minimal standby load:** Some generators, designed primarily for on-grid standby use, draw energy—even when not running—for control functions, charging the starter battery, and even for block-heating in cold climates. This may be acceptable for use with utility power, but not for off-grid systems. Look for a generator that has no parasitic draw when off, or expect to add a separate small PV module and charge controller to keep the starting battery charged.

- **Engine speed:** In general, quality conventional generators run at lower speeds—typically 1,800 rpm versus 3,600 rpm—which directly translates into longer life. An 1,800 rpm unit will also operate more quietly, with less vibration and lower fuel usage.

- **Onboard starting battery charging** when the engine is running. Generators designed for on-grid “residential standby” operation sometimes require an external battery charger.

- **Liquid cooling,** rather than air cooling. Liquid-cooled machines will run quieter and, being thermostatically controlled, will run at a more even temperature year-round, resulting in longer life.

- **Sound-attenuated housing** and a residential muffler for quiet operation.

- **Field-configurable voltage output,** unless the supply voltage matches your needs.

- **Floating or unbonded neutral-to-chassis connection.** Quality generators allow the neutral conductor to either connect to the generator chassis (for prime power application) or remain separate from it. Portable generators are seldom properly grounded, so manufacturers ground the neutral output conductor to the chassis. When connected into a grounded power system, however, this presents a safety hazard, as the neutral is now bonded to the ground at two places—one in the power system AC (such as in the main AC service panel) and one in the generator—and the safety ground wire becomes current-carrying. Some units also include AC ground-fault protection, which is incompatible with connection to a grounded power system. There is no simple, code-compliant solution to this. The safest noncompliant approach is to bundle an insulated, green ground conductor with the power conductors between the generator and the main ground bus, which serves to ground the chassis and minimize shock potential.

- **A well-earned reputation for after-sale support** by the local dealer. Even the best generator will eventually need service and repair, often on-site.

- **A warranty of at least two years,** valid in off-grid applications.

C-Rating

The term *C-rate* refers to the rate of charge or discharge of any battery, expressed in relation to the battery’s capacity. A C/10 rate on a 220 amp-hour battery string would be 22 amps (220 ÷ 10); a C/20 rate would be 11 A (220 ÷ 20). For long service, batteries must be charged at a C-rate sufficient to overcome internal resistance under varied conditions and age. As a general rule, flooded lead-acid batteries need at least a C/20 rate to charge and equalize properly. A C/7 charge rate is about the highest that these batteries can tolerate.

Look for a generator that includes electric start and a panel switch that internally reconfigures the generation coils to provide full output at either 240 or 120 V—common on higher-quality portable generators.

Courtesy www.positiveenergysolar.com

Selecting Your Fuel

Generators are fueled by gasoline, propane (or its cousin, natural gas), diesel, or biodiesel. The least expensive generators and nearly all portable units use gasoline, which offers some advantages—mainly that gasoline is familiar and manageable by the unskilled user. However, it's highly flammable, and fuel storage will need to be a consideration. Allowed to sit in a generator's fuel tank, gasoline will eventually deteriorate, leading to clogged orifices and preventing the generator from starting when needed. Cold-starting also requires engaging a choke. Most auto-start generators are not gasoline-fueled for these reasons. A gasoline generator may be best suited to applications where it is only used occasionally and the gasoline is drained (or run out) after each use.

LP gas (propane) is commonly used in higher-quality stationary generators. Many off-grid homes already have an LP tank and lines for cooking and heating, so the fuel is convenient and relatively safe. Propane has an almost unlimited storage lifespan. LP generators will generally start reliably down to about 10°F. Natural gas and propane burn cleaner than gasoline and diesel, and wear on internal engine parts is reduced.

With some notable exceptions, diesel generators are typically long-lived and high-quality—and relatively expensive. However, the fuel is best suited to warmer climates, as it gels below freezing temperatures. The drawback to diesel fuel is that, compared to natural gas or propane, it's a "dirtier" fuel, producing more pollution. Fuel storage requires extra care against spills and leaks, and may even be regulated. For the eco-tinkerer, diesel units may also be run on biodiesel or either virgin or waste vegetable oil, taking the appeal of "living on renewable energy" to a greater level. Vegetable-based fuels don't generally need additives to prevent gelling; the fuel is heated instead.

3 Courtesy www.positiveenergysolar.com

This Onan RS20000, 20 kW LP generator is a perfect match for four OutBack VFX3648 inverters (see photo at right).

Sizing a Generator

As a general rule, a generator should be able to supply the full charging capacity of your inverter, plus loads that typically run while charging and provide some reserve capacity. This both minimizes runtime and maximizes C-rate—the charge rate necessary for good battery care. Generators used in home systems will vary between about 2,500 watts and 20 kilowatts of continuous rated power.

Often, a generator is purchased before the power system is designed, as an early source of power for construction and water supply. The result is that the RE system designer must take the existing generator and adapt the system design to best use it—a backward approach to system design. A better plan is to consider a generator as part of the overall power system design. The preferred approach to sizing a generator starts with the battery bank.

Automatic Generator Start

Autostart generators are capable of remote start, meaning that these units can be started by an external signal, such as one that might come from an inverter when it detects a set battery voltage level. The control over the generator's operation—that is, when to run and when to stop—is external to the generator, while the generator provides its own safety protection, such as shutoff for low oil level, overheating, and other factors.

Among remote-start generators, the simplest is the "two-wire start," in which a closed contact tells the generator to start and run. When the contacts open, the generator stops. All inverters with generator-start capability can control the generator in this method, as can other system components such as a manual switch, a voltage-controlled relay, a threshold signal in some system monitors, and even a signal triggered by a big load.

Automatic generator operation is at best a mixed blessing. In theory, the inverter calls for the generator to provide backup charging power whenever the RE source proves insufficient. However, numerous real-world bugs can interfere with such seamless operation. Automatic operation can lead to a system owner failing to perform regular maintenance, and neglecting something as simple as checking oil levels can cause unintended problems that aren't noticed until the entire system shuts down. Poor programming can lead to excessive runtime and fuel consumption, yet not guarantee that batteries are adequately charged.

The most likely path to eventual failure is total dependence on a generator in an unattended system. "Auto-generator start systems built into all of the inverter systems should be viewed as a convenience device," cautions Christopher Freitas of OutBack Power Systems, "not as a comprehensive, 'bullet-proof system' which will operate 100% of the time."

Longtime installer Todd Cory is more blunt: "I *never* configure autostart generators. Having a machine automatically start/stop while unattended is at best a recipe for damage to gear and, at worst, a fire that could destroy the entire homestead."

This large home system uses four OutBack charger/inverters in a 120/240 output configuration. The middle two inverters are mainly used to achieve a C/13 charge rate for 2,200 Ah of batteries at 48 V.

Most PV arrays for off-grid homes will be sized to meet or exceed design loads for part of the year. This seasonal duration may cover all except the heart of winter in the sunny Southwest, or may only cover half of the year in northern climes. Battery banks are typically sized to provide two to four days of autonomy (time the batteries can supply energy without further charging), depending on the seasonal climate and other factors.

Because arrays and batteries are sized to different purposes, the array is seldom large enough to meet even the minimum C-rate needed to routinely fully charge and regularly overcharge (equalize) the battery bank. Hence

Some inverter/chargers, like this Magnum MS4448AE, can accept either 120 or 240 VAC output from a generator.

Generator Sizing

The example we'll use is an 1,800-watt PV system installed at an off-grid home in the Midwest. The battery bank is two strings of flooded lead-acid batteries, with eight 6 V batteries in each series string. The battery bank is rated at 700 amp-hours at 48 VDC nominal—or about 60 V under charge.

The *minimum* charge rate, C/20, is 35 A (700 Ah ÷ 20), but the 1,800 W PV array will produce 30 A at best (1,800 W ÷ 60 V)—less than desired. With cloudier weather, the generator and inverter become even more important to achieve the desired charge rate. An ideal charge rate would be about C/10, or 70 amps. This will minimize generator run time, while still allowing the PV array to contribute 25–30 amps when it can without exceeding the batteries' maximum charge rate.

We would like a charger, usually integrated into the inverter, that can hold a 70 A charge rate. Sticking to the most commonly used inverter/chargers, the Xantrex XW4548 is rated at 85 A, which is plenty. The Magnum MS4448AE puts out 60 A, which is close enough for our needs. The largest OutBack VFX3648 is rated at 45 A, so one solution would be a pair of FX3048Ts, each rated at 35 A DC, for our desired 70 A total. Let's assume the Xantrex XW4548 inverter for this example. According to the manufacturer, the AC input charging current necessary for this inverter to create the full charge rate is 24.8 A at 240 VAC, or 5,950 W. This gives us a starting place for sizing a generator to power this inverter.

First, adjust for maximum load. As a rule, most generators run best close to, but not at, maximum output. 85% is a commonly used figure, although some high-quality units can be run at 100% of their nameplate rating. So 5,950 W ÷ 85% = 7,000 W, assuming a quality, accurately rated generator. Next, adjust for elevation and temperature. Assuming sea level, adjusting for elevation is not necessary (see "Elevation & Temperature Effects" below). To adjust for temperature, assume 100°F operation, which is an approximate derate of 6% for a generator rated at 60°F. This results in 7,000 W ÷ 94% = 7,447 W—a 7,500 W generator should be sufficient. If there are loads that will be run while charging the battery, apply the temperature and elevation adjustments to them and then add this amount to the sizing total.

Finally, make sure the voltage output of the generator matches the input of the inverter/charger. Traditionally, off-grid inverters have been based on 120 VAC input and output. In this example, matching the inverter's input voltage to the generator's output is no problem since this inverter/charger supports both 120 and 240 V configurations.

Elevation & Temperature Effects. Power output of all generators is rated for use at sea level. As elevation above sea level increases, air becomes thinner, with less oxygen. The result is decreased performance. Most generator owner's manuals include an adjustment factor, but a general rule is to derate 3.5% per 1,000 feet above sea level. For example, at 5,000 feet, a generator will produce about 82% of its rated output.

As the ambient air temperature increases, the engine and alternator heat up, which decreases both efficiency and power output. Generator manufacturers will rate power output as low as 60°F and as high as 120°F; there is no common standard. Using both rated output power and temperature as starting points, a typical deration is 1.5% per 10°F above rated temperature. For example, a generator with a rated output of 10,000 W at 60°F will be capable of 9,400 W at 100°F.

Modified-Square-Wave Inverters

Most modern off-grid PV systems use sine-wave inverters. But plenty of older modified-square-wave inverters—what are still euphemistically marketed as "modified-sine-wave" inverters—remain in use today. The most common are the Xantrex (Trace) DR and earlier U-series, and most RV and marine inverters.

These inverters have special generator requirements. While modern inverters use the entire power waveform (the technical term is "power-factor-corrected"), older modified-square-wave inverters use only the voltage peak of each wave. What this means is that the generator must maintain full peak voltage under a charging load.

High-quality generators are able to maintain peak voltage (the ideal is 164 to 170 V on a 120 V wave) under load. But cheaper generators tend to have a flat voltage waveform —that is, the measured RMS voltage may be accurate, but the peak is lower than 164 V under load. This is adequate for occasional power tool use, but can result in very low charging current—the familiar mystery of low-DC charging current from a well-running generator.

Three possible solutions address this problem. The first is to oversize the generator, so that it is lightly loaded while charging. Second is to increase engine speed, which works in some generator-inverter combinations by increasing voltage proportionally. The best solution is to use a modern inverter–generator. These units maintain full peak voltage up through their maximum load and, if sized correctly, will enable a modified-square-wave inverter to charge at its full capacity. Most inverter–generators have 120 VAC output, which is ideal for a single-inverter power system.

the need for the generator, which can add the necessary charge current to get this done, and may be even the only contributing charging source during winter—so it should be sized to handle the job.

AC Voltages

Typical utility power is split-phase 120/240 VAC. If you look inside a home's electrical distribution panel, you will see three non-ground wires coming in: two "hot" conductors and one "neutral" conductor. The voltage between each hot and the neutral conductor is 120 V, and the voltage between the two hot legs is 240 V. Most off-grid homes have only one hot conductor, and operate at 120 V.

An off-grid system's generator must be matched to the voltage needs of the inverter/charger. Generators provide AC output in one of four ways:

- **120/240 V with full-rated power only available at 240 V.** Most inexpensive, homeowner-grade generators are set up this way. The rated output is the combined wattage of both 120 V legs, and at most, half of the rated output is available at 120 V.

- **120/240 V with a switch** that internally reconfigures the power generation coils to provide full output at 120 V when desired. This is a valuable feature and is fairly common on higher-quality portable generators.

- **Straight 120 V:** Many of the newer "inverter-generators" (see below), and most models designed for RVs, put out power only at 120 V. Small, portable units (less than 2,000 watts, generally too small to use effectively as charging sources) are only 120 V.

- **Field-reconfigurable:** Most top-quality generators may be reconfigured to offer either full-output 120 V or 120/240 V by changing the connections of the output wires inside the generator. This task is best handled by a generator service technician or skilled RE installer.

Most inverters manufactured since the late 1980s can only receive 120 V input from a generator. For most off-grid homes, this is not a problem, since 240 V loads are typically large bulk loads from water heaters, clothes dryers or electric ranges that are inappropriate in an off-grid home. With the exception of AC well pumps, off-grid homes are unlikely to have 240 V loads.

When a typical 120/240 V generator that is not capable of full output at 120 V is paired with a 120 V inverter, two problems occur. First, a 120/240 VAC generator is only capable of half of its rated output when connected to the input of a 120 V-only inverter. Second, the load on the generator is unbalanced, with one 120 V leg fully loaded and the other unloaded. This imbalance can lead to premature generator failure.

This means that the less-expensive generators are least able to efficiently back up the most common inverters. For example, a low-cost generator may be specified at 5,500 W maximum output. But the usable "rated" output is not "maximum" output. Similar to the way an inverter's continuous-duty capacity is compared to its capacity to meet larger surges, "rated" output is the level of power a generator can deliver continuously. Usually, it's about 85% of the "maximum" power, although some lower-quality generators

Inverter–generators, like this Honda EU6500is, can adjust engine rpm to meet loads while an onboard inverter keeps the output waveform on spec.

Courtesy www.hondapowerequipment.com

Generators in Grid-Tied Systems

Batteryless grid-tied PV systems are in many ways the essence of simplicity. Reliable and essentially maintenance-free if skillfully installed, they are ideally suited to homes accustomed to utility power. But the chief limitation to batteryless PV systems is lack of backup power during utility outages. If you want backup power for "critical" loads, such as refrigeration or lighting, there are three common approaches.

The first approach is to **install a battery-based grid-tied system**. While a battery backup system works well if designed and installed well, it will add cost and complexity to the system. It will be slightly less efficient than a batteryless system, as it must balance AC production with charging and maintaining batteries, rather than solely maximizing AC production into the grid. It also will usually supply only enough stored power to support selected house loads during a typical short-duration utility outage, though RE-generated energy will extend the length. Off-the-shelf packages are available to support a modest load profile during an outage of short duration: A typical battery bank of four 100 amp-hour sealed batteries only provides 4 kilowatt-hours of usable power before it must be recharged; this would be a hard limit for most households at night or during a snowstorm.

Adding a generator to a battery-based grid-tied PV system will extend the system's backup duration indefinitely—until the fuel runs out or the residents get tired of the noise. With good design and execution, this approach can work well. However, the system quickly reaches complexity beyond the skills of most homeowners and novice installers. It must be set up and programmed to work reliably and automatically, and must be tested and exercised regularly if it's to be relied upon. Plus, not all manufacturers' equipment is capable of integrating both generator and grid inputs—Xantrex's XW system will; OutBack's will not.

Courtesy www.kohlerpower.com

The third approach is to **install a generator and transfer switch** as a backup source during outages without tying the systems together. The disadvantage is that switchover to the backup source is not instantaneous, and with batteries eliminated, the generator must run continuously whenever backup power is needed. Advantages include the simplicity of separate, conventional systems, each supported as necessary by its separate provider and each optimized to a single task. An entire market has developed for generators for residential standby use.

All three approaches are considerably more costly than batteryless systems, for two main reasons. The first is simply the added hardware and complexity. The second is the cost of modifications to a home's wiring. Since none of these approaches typically has the capacity to run an entire home, key loads are identified as critical to operate during an outage. These usually include some lights, a heating source, refrigerator and freezer, and communications (computer, television, and Internet). Key circuits must be identified and moved from the home's main breaker panel to a "critical loads" panel to be fed by the backup source. Unless specifically planned during the home's original construction, this is a labor-intensive job for an experienced electrician.

If a grid outage is no more than an inconvenience, install a batteryless system and enjoy the occasional meal by candlelight when the grid goes down. If power during an outage is critical and typical outages are infrequent and of short duration, a grid-tied system with battery backup is a good choice. If an outage would be potentially catastrophic, such as a winter ice storm that can cause power to be lost for days in subfreezing weather, the battery and PV recharge capacity of a battery-based grid-tied system will be insufficient, and a backup generator will be a wiser choice. Consult with a reputable local RE installer or generator dealer to determine the best approach for your needs.

are not even capable of their "rated" capacity. How much power is really available? First, check the rating carefully: the 5,500 W rating is likely to be around 4,700 W in continuous duty, such as battery charging through an inverter. Second, the continuous rated power is available only at 240 V, so a single 120 V inverter can only access half of this output capacity, or 2,350 W.

One solution is to use a balancing autotransformer to step down the 240 volts to 120 V before sending it to the inverter. This allows the full power and both 120 V legs to work in balance. However, a typical autotransformer for this purpose retails for more than $500, making the "low-priced" generator much more expensive.

Another solution, usually practical only in larger systems, is to use a stacked pair of inverters to both receive and produce 120/240 V power. This is a common approach with OutBack inverters. A few modern off-grid inverters, including Magnum's AE series, Xantrex's XW, and Apollo's TrueSineWave are configured as 120/240 V split-phase units. These units are able to use both 120 V legs of a generator to provide balanced charging from both hot legs. The new Silent Power SP4024 inverter can use either 120 or 240 V input. No step-down transformer is needed with any of these inverters.

Another option is to select an inverter-generator, a relatively recent development. The inverter (which cannot substitute for the RE system's inverter) is an integral part of

An autotransformer can convert 240 V output from a generator to 120 V needed by an inverter's charger.

the generator, electronically synthesizing the voltage, current, and waveform, while maintaining full-peak voltage up through their maximum load. As the 60-hertz AC waveform is not dependent on engine speed, the engine speed varies according to the load. This allows an accurate pure-sine waveform, while reducing fuel consumption and noise.

Recommendations

Generator models are rapidly evolving, with new models entering the market and old favorites being discontinued. Most of the reliable, small generators of years past were made obsolete by California's emissions standards and changing markets. Newer models have been developed primarily for the on-grid home standby market, rather than for stand-alone use. Standby models, intended for backup power during utility outages, are marketed as low-maintenance home appliances. They will commonly require utility power to maintain controls and charge the starting battery, and even for running block and intake heaters in cold weather—all unacceptable loads in off-grid use. In addition, fierce competition in this market has encouraged an emphasis on low price over high quality. There is a clear and unmet need for simple, reliable, commercial-grade generators not designed for the residential standby market.

The safest bet is to buy a well-respected brand, or at least a generator that comes with a brand-name engine—it will be much easier to find parts and service for a well-established brand than for some no-name model. Finding a high-quality used machine with low hours and evidence of proper care may also be a possibility. Consider also an inverter–generator, as these are gaining wide acceptance, with sizes available up to 6.5 kW. Honda, Yamaha, Robin, and Cummins make high-quality inverter-generators. All run on gasoline, but some of these brands may be converted to LP gas without voiding manufacturers' warranties.

Among conventional portable units 6 kW or less, Honda's EM or EB, and Yamaha's EF and YG series have been well regarded for years. Multi-Quip and Robin—made by Fuji Heavy Industries and marketed under the Subaru, Makita, and Baldor names—also have solid reputations.

In higher-quality commercial units, Kohler's 10ERG is a well-regarded model developed for the RV market and adaptable for off-grid use. Onan makes several adaptable units, including the RV QG 6500LP, RS 12000, and RS 20000 LP, the latter two suited to larger systems. There are some nice Onan diesel inverter/generators (the HQD series) up to 18 kW.

Notable negative comments have generally been directed at the cheapest generators, with poor waveforms, inflated output claims, and lack of long-term reliability. Also, avoid knockoffs of well-known models, especially low-cost inverter-generators now on the market. Reliability is unknown, and repair parts may be unavailable.

Maintenance, Safety Features & Warranties

On most generators, maintenance is necessary but not difficult. Every generator includes an owner's manual with a maintenance schedule and instructions. Typical maintenance includes checking and changing oil, fuel filters, and air filters. Less-frequent maintenance includes adjusting valves and changing spark plugs and coolant.

Nearly all generators include an automatic shutoff switch, which activates if the oil level drops too low. Additional safety features designed to protect the generator are included on better quality units. These may include overtemperature/overload, overcrank (cranking an already-running engine), and over/under voltage and frequency. Some units use a digital controller capable of alerting about a variety of faults.

As you select your generator, be sure to read the fine print of the warranty. The best standard warranties I have seen are for a period of two or more years (with extensions available at extra cost), cover parts and labor, do not exclude off-grid applications, and are transferable. A few include on-site service. Some warranties are voided if gasoline engines are converted to LPG while others allow the aftermarket conversion.

Access

A PV system installer since 1988, **Allan Sindelar** (allan@positiveenergysolar.com) founded Positive Energy Inc. of Santa Fe, New Mexico, in 1997. He is a licensed commercial journeyman electrician and a NABCEP-certified PV installer.

This article was prepared with the assistance of **Roy Butler** of Four Winds Renewable Energy, Arkport, NY; **Tad Jennings** of Power Generation Services, Albuquerque, NM; **John Klesk** of Cummins Power Generation, Minneapolis, MN; **Terry Graybeal** of Backwoods Solar, Sandpoint, ID; and **Tom Bishop** of Sunelco, Hamilton, MT.


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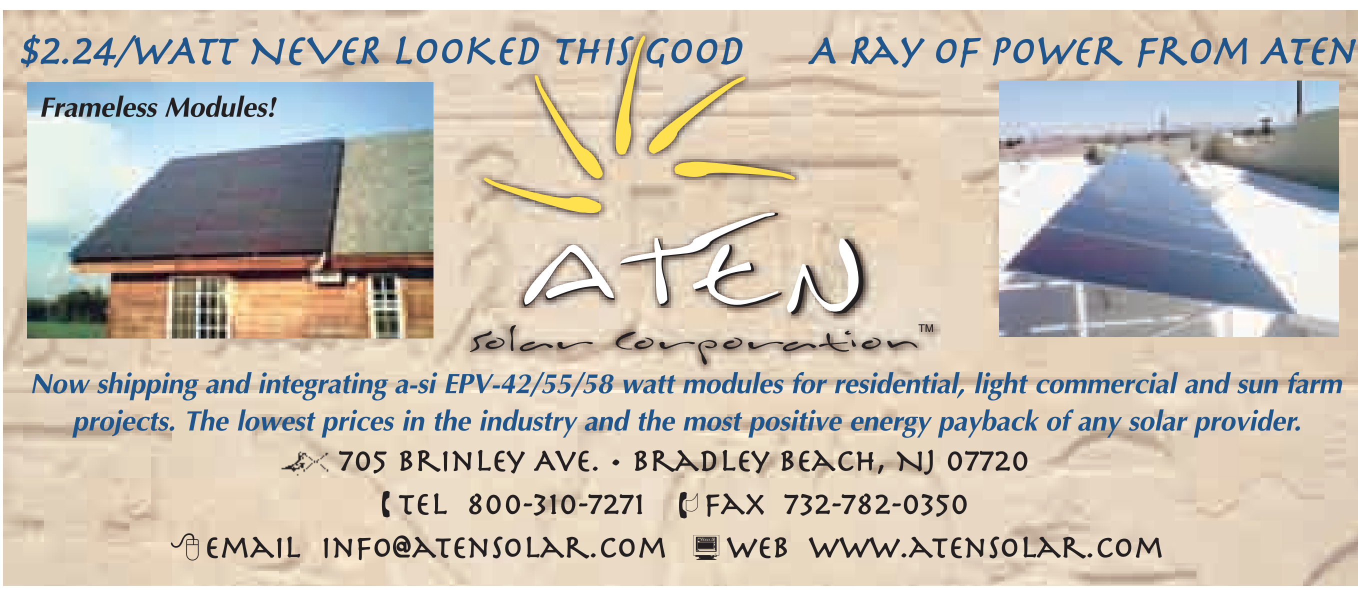
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Array to Inverter
& Things Between

by John Wiles

The direct-current world of PV systems can be somewhat unfamiliar to many electrical system designers and installers, and there are sometimes details that get overlooked in designing, installing, and inspecting these systems. This *Code Corner* covers a few of those commonly neglected details

Conductor Types

Single-conductor, exposed cables (type USE-2 or the new PV cable/PV wire) are used as module interconnecting cables. In each circuit, there is a need to be able to distinguish which conductor is the grounded conductor. For cables smaller than AWG #4, generally the requirement for grounded conductors is to use a conductor with white (or grey) insulation. However, both of these cable types will generally be available only in basic black. The *National Electrical Code* Section 200.6(A)(2) notes that this black cable, even when smaller than #4, may be marked "white" (with electrician's tape) as a grounded conductor at all termination points at the time of installation.

Normally, exposed single-conductor cables are transitioned to a conduit wiring method when the circuits leave the PV array. While it's possible to use USE-2/RHW-2 or PV wire, THHN/THWN-2 is typical, since it is less costly. The "2" rating is needed to withstand the high temperatures of conduit exposed to sunlight and in outdoor, wet-environment applications (Section 310.15(B)(2)).

Unfortunately, #14 through #10 conductors with THHN/THWN-2 insulation are not widely available. THHN/THWN is available, but it doesn't have the proper rating for these conditions. However, as inspectors start applying 310.15(B)(2) of the *2008 NEC* to rooftop HVAC installations, demand will increase for the small-conductor THHN/THWN-2 cables. For now, I tend to support the use of USE-2/RHW-2 (with a white marking for the grounded conductor) in the conduits, although the *NEC* does not clearly state that it can be used with markings in that location. XHHW-2 would also be a suitable alternative.

All circuits in a PV system, as in other electrical systems, must be wired using a *NEC* Chapter 3 or Article 690.31 method that is suitable for the application and the environment. However, there are frequent questions about the circuits between the PV DC disconnect and the inverter. As far as the *NEC* is concerned, if these circuits are in protected environments, they could be wired with type NM cable. Although they are still, technically, PV output circuits, after the PV DC disconnect, they no longer represent the same hazard and do not have to be in metallic raceways unless required by the authority having jurisdiction (AHJ).

Conductor Color-Coding

In the recent past, most PV arrays have grounded the DC negative conductor, which is colored white. Newly installed arrays may ground the DC *positive* conductor (also colored white). Although no designated color codes exist for the ungrounded conductor, common sense would suggest that on a negatively grounded array with the negative conductor colored white, the positive, ungrounded conductor would be most clearly marked and understandable if it were a different color—say, red. However, many installations use a *black* positive conductor, which is still acceptable under the *NEC*. In the positively grounded systems where the positive grounded conductor is colored white, the ungrounded negative conductor would be most clearly understood if it were black.

The increasing use of transformerless inverters will dictate the use of ungrounded PV arrays (Section 690.35). Then we can adopt a "red is positive" and "black is negative" color-coding, since there will be no grounded conductor. The newest bipolar PV arrays and bipolar inverters have red positive ungrounded conductors, black negative ungrounded conductors, and white grounded conductors.

As before, the grounded conductor in a PV DC disconnect should never be switched, although bolted, isolated, terminal-block connections are acceptable.

Inverters

Utility-interactive inverters range in size from 175 W to 1 megawatt and new models are being introduced regularly.

This inverter comes with internal disconnects, but the inverter electronics cannot be removed separately for servicing. The separate external disconnect can de-energize the DC wiring inside the inverter.

These inverters will be tested and listed to UL standards by an independent agency—usually Underwriters Laboratories (UL), or CSA, ETL, or TUV Rhineland, all of whom are designated as Nationally Recognized Testing Laboratories (NRTL) by OSHA for testing and listing PV modules, inverters, combiners, and charge controllers.

Some inverters have only a single set of DC input terminals. With these designs, an external PV DC disconnect must be installed. Very low-powered inverters, like the Enphase microinverter, are permitted to use the DC and AC connectors as the required disconnects because they can be safely opened at their low current and voltage levels. Even if the inverter has more than one set of input terminals for parallel separate strings (source circuits) of modules, external DC disconnects must be used on each input. Disconnects may be bolted terminals, connectors, breakers, or bladed switches. Square D has a self-certification rating of 600 volts per pole on their H361, 2, and 3 fused safety switches and unfused safety switches. Each input must still have a disconnect, or if a disconnect has multiple poles rated for 600 volts, it may be used to disconnect multiple inputs.

Other inverters have internal DC disconnects or disconnect housings that attach to the main inverter section containing the electronics package. The method used to mount the internal disconnects, the ease and accessibility of the disconnects, and the manner in which they are separated from the inverter electronics vary between products. The installer and the AHJ must reach a mutual conclusion on the suitability of these disconnects for meeting the various requirements in the *NEC*.

Since the inverters are listed with the disconnects, it can be presumed that the disconnects are properly rated for the DC load break operation. If the inverter were installed in a location that meets Section 690.14 requirements for the main PV DC disconnect, then it would appear that the internal disconnect would meet this requirement.

Meeting the requirement for maintenance disconnects (690.15) will require additional considerations. If the inverter were to require factory service, can the energized PV source or output circuits be disconnected from the inverter safely when there is no external disconnect? If a disconnect housing is attached to the inverter and that housing does not have to be removed to service the inverter, then some degree of safety is assured. However, if the energized conductors must be disconnected from internal switches and pulled through small conduit knockouts, the situation must be examined carefully. Will qualified people who know how to disable the array be performing the removal? Or is there a chance that energized conductors could be pulled through the knockouts?

DC Input Fusing

Some models of inverters have DC input fuses mounted inside the inverter or inside a combiner/disconnect device attached to the inverter. The smaller fuses (30 amps or less) are usually mounted in "finger-safe" fuse holders that allow the fuse to be safely replaced in an unenergized state. However, fuses—anywhere in the PV system—rated at greater than 30 A are mounted in exposed fuse holders or bolted directly to a DC bus bar. One side of each fuse is tied together with the DC input of the inverter. The other side of each fuse is hardwired to the output of a PV DC combiner. These combiners are placed throughout the PV array—and in large, commercial systems, sometimes scattered over acres of real estate. Although the inverter can be turned off and the DC input capacitors allowed to discharge (takes up to 5 minutes), each fuse is still energized from its own input and the combined inputs of all of the other fuses through the common bus bar. The only way to safely service these fuses is to find all of the combiners that feed the inverter's fuses, and open or pull every source circuit fuse (those less-than-30 A "finger safe" fuse holders). An optional disconnect at the output of every combiner speeds this process and makes servicing the recombiner or inverter fuses safer—but all disconnects must be located and opened.

For large systems with several series strings, a disconnect at the output of every combiner eases servicing the recombiner or inverter fuses.

When these fuses are present in the input of the larger inverters, providing for safe servicing means installing a DC disconnect near the inverter on each DC input to a fuse.

These co-located disconnects can be easily opened. With the inverter turned off, the fuses can be safely removed in a de-energized state.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. IEE provides engineering support to the PV industry and a focal point for code issues related to PV systems.

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV" and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005* National Electrical Code: *Suggested Practices*, by John Wiles


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Slowing Industrial Greenhouse Gases

with Cap & Trade

by Michael Welch

What "cap 'n trade" isn't: a kids' cereal that offers baseball cards as an in-the-box premium. What it is: one of the most discussed methods available to meet the carbon-reduction needs of a market-based economy.

According to the U.S. EPA's "Inventory of Greenhouse Gas Emissions," industrial end use contributes 27% of CO_2 from fossil fuel combustion in the United States, second only to transportation (33%). Residential emissions come in at 21%; commercial emissions make up about 18% of the total. If our country is to meet the international goal of rolling back greenhouse gas production by at least 80% below 1990 production levels—and achieving this by 2050—we need to get industry started on the right path as soon as possible. There are several different solutions that have been suggested to reach the goal.

Laissez-Faire

The first method, and the one that industry prefers, is to just leave industry and commerce alone. The theory, espoused primarily by those that have something (namely, profit) to gain from it, is that in a free market, customers will choose the companies that are the least polluting. Why? Because customers care about the environment and are willing to spend extra for "green" products and avoid buying unneeded items—all in support of their knowledge and beliefs. As other companies discover that consumers are avoiding their products, they will be forced to clean up their acts or perish from lack of business.

But this requires that consumers have near-perfect knowledge and understanding about each industry and the related pollution involved in a product's manufacture. The theory also relies on the idea that consumers have the psychological wherewithal to go with the greater good and forego their personal desires to consume.

The problem with implementing this theory is that industry and commercial interests spend billions of dollars each year to spin the facts—or keep them undercover. One example is industry-funded global warming "skeptic" organizations that deny there is a problem. Industry also spends billions each year advertising their goods, and they do so in ways that are scientifically designed to influence our subconscious minds, creating the desire to consume products that we otherwise would not want or need and making it tougher to choose differently. We must dismiss the idea that a free market can effectively address climate change.

Legislate & Regulate

Another potential method is through direct government regulation, which has proven effective in other areas of environmental protection. This method does not rely on the consumer to choose an environmentally friendlier product, but rather relies on legislators and other elected officials—who theoretically represent our interests—enacting laws and regulations to protect the environment. This method has worked well for eliminating polluting methods for which there is a reasonable substitute—like the ban of DDT use in favor of other insect eradication methods.

But banning the release of CO_2 is not a possibility, at least not with current scientific knowledge and accepted industrial practices. And flat-out telling industry that they cannot release more than a certain amount is not politically viable, considering the amount of influence that industry has on our government. This is borne out by the inability of government to regulate other crucial problems, such as the amount of particulates that are released into the atmosphere from coal-fired power plants, which tend to be located in the poorest communities—affecting those with the least political clout.

Impose a Carbon Tax

Imposing a carbon tax on any market action (industrial or consumer) that releases carbon is a financial method of reducing greenhouse gases that has been bandied around. For example, a concrete company would be more likely to implement energy-saving techniques if they had to pay a high tax on the amount of fossil fuel energy they consume. Carbon

taxes can even affect the decisions of consumers—tacking on a significant tax to gasoline sales might make buyers at the gas pump change their driving habits.

But a carbon tax lacks an important element—some way of limiting the amount of carbon that is allowed to be released. For example, cigarette taxes have had little noticeable effect on the amount of cigarettes that are sold. Sure, the taxes are good at helping to offset government costs relative to smoking (like smoking-prevention education efforts and health costs), but that's not enough for dealing with global warming. Climate change has to be halted, not mitigated.

Turn It Into a Business

If business is best at doing business, and taxes and regulation are unlikely solutions, maybe it makes sense for the solution to be commerce-related. Involving commerce automatically arouses the profit-making interests of capitalists, which can remove political barriers to implementation. This is the "trade" part of "cap and trade."

Industry would be allowed to sell and buy the right to pollute. Businesses that are successful at decreasing their CO_2 emissions can sell their unused pollution-rights allowances to other businesses that are not reducing their emissions. Sellers then make money from their decrease, offsetting the cost of achieving the reductions, such as investment in energy-efficiency measures or pollution-reduction equipment. The businesses that buy the rights to pollute see their costs go up for not implementing adequate reductions. The failure of the free market to consider the environmental effects of production is addressed by artificially creating a market to financially encourage industry to do better at carbon reduction.

However, this alone is not enough to begin reducing emissions overall. Industries with limited or no competition (or those that collude with their "competition") could merely pass the additional costs of polluting on to the customers. Therefore, a "cap" on the amount of carbon an industry is allowed to produce is the second part of this method. This serves as the control for total emissions, industry-specific emissions, and how much each company would be allowed to emit as a starting point for trading. Setting a cap low decreases the supply of carbon credits, increasing the *income* for companies able to *reduce* emissions while increasing the *cost* for those unable to do so. Setting a cap too high would cheapen the value of emissions credits, rendering the system ineffective, with little incentive to change. The caps would be adjusted regularly, in accordance with recent climate science.

Precise setting of the cap to meet short-term goals is one key to success. The overall goal is an 80% reduction by 2050, but goals need to be set for nearer term, so that the reductions are spread throughout the timeline and not all compressed at the end. A midterm goal of 15% to 20% reduction from current levels by 2020 is sometimes mentioned. Not only are the effects of reduction greater if introduced earlier, but the overall long- and midterm reductions will be harder to meet if action is delayed until the end of the period.

The "emissions allowances" need to be spread across the various polluting industries in a way that is fair and meets carbon reduction goals. Industries would likely start with some minimal allowances, in proportion to historical emissions. But beyond those, a favored method is to insert credits into the market by an initial auction, and then use the proceeds of auctioning to invest in renewables, efficiency, fossil-fuel power plant retirements, and other CO_2 reduction programs.

Other interesting possibilities might accompany this type of market, depending upon what is allowed by the laws setting it up. For example, individuals and environmental groups that wish to speed up the reduction of CO_2 might buy allowances and retire them, thus driving up their value and making it more practical for industries to spend money on decreasing their emissions. Still others might invest in allowances, on speculation that they will have a higher value some day. These credits could become universally negotiable, as tradable as stocks and bonds and as valuable as cash.

C & T Criticism

While appearing to be the best of the possible solutions, cap and trade is often criticized for being difficult to implement. It does require fairly exact determinations of total reductions needed. And deciding how to apportion those reductions and allowances based on historical emissions is a difficult task in a regulatory atmosphere of potentially large, bungling bureaucracies, and the undue influence of industry and commercial interests.

Another criticism of cap and trade is the fear that an open marketplace for allowances will leave a lot of room for manipulation, much as what happened when California opened its energy markets about 10 years ago (remember Enron?). A loophole found and exploited in the market could set advances back far enough to make the critical 2050 goals even more difficult to attain.

Cap and trade has detractors that feel implementing a market solution will distract from what really needs to happen—a sociopolitical awakening to the fact that our industrial-based society *must* change. They feel that such a system will deter our ability to adequately deal with myriad other parallel problems, like other forms of pollution, environmental injustice, the further shifting of wealth to the wealthiest, and diminishing natural resources.

A new version of C & T—"cap and *dividend*"—has recently been introduced in Congress—and it appears more palatable to climate change activists. It calls for auctioning 100% of carbon emission allowances, with none given away to industries based on historic usage. Revenues from the auctions would be distributed directly to U.S. citizenry as taxable dividends. Further, it would simplify the capping by going directly to the first sellers of coal, oil, and natural gas.

That's a lot to think about—but *Home Power* readers have an advantage. We know that no matter what the governments of the world come up with, we as individuals can take our share of the responsibility by implementing energy-efficiency measures, using renewables, and keeping an eye on our carbon diet.

Access

Michael Welch (michael.welch@homepower.com) is reducing his own carbon footprint, while insisting that his government do the right thing.

Rockin' ...in the Free World

by Kathleen Jarschke-Schultze

According to the Freegan Web site (www.freegan.info), Freegans are people who employ alternative strategies for living, based on limited participation in the conventional economy and minimal consumption of resources. Freegans embrace community, generosity, social concern, freedom, cooperation, and sharing, in opposition to a society based on materialism, moral apathy, competition, conformity, and greed.

I first heard about the Freegan movement on television from a reporter who went on a "trash tour"—an organized tour of grocery store and restaurant trash cans in New York City. Besides being appalled at how much good food is thrown away every day, I was initially jealous of those people living in a city where there were dumpsters to raid. Then common sense prevailed—I love our rural lifestyle. I was curious though, and enjoyed reading about Freeganism on the Internet.

Raina Kelley, a reporter for *Newsweek*, went beyond the trash tour and spent a month as a Freegan. Her blog, Freegan Girl, details her experience. She started out with nine rules, which include being vegan (eating no animal products); not throwing away what she already has just to buy "green," but using products until they're gone; using only eco-friendly transportation (unless it is a matter of personal safety); reducing her energy bill by 50%; and opening a "Freedom" savings account to bank all the money she saves (goal: to give her the freedom to quit working, move upstate, and read used books). Most importantly, Raina says, is to be mindful of the impact of her actions on the Earth. *Newsweek's* lawyers wouldn't let her actually root around in dumpsters because her employer's insurance would not cover it. In some places this is illegal, anyway.

Although Raina brought Freeganism to the attention of the mainstream, the movement has its roots on the West Coast, especially in Seattle and Portland. I know quite a few old hippies that started dumpster diving in the 1960s. I can say that with absolutely certainty because I am one; rescuing usable items from the trash has always been second nature for me. In the past, Bob-O, my husband, threatened to accompany me on dump runs because I always brought home more than I took. I picked up the best foldable steel animal transport cage, for example. Now we have a rule: If I bring anything home, I must get rid of something of the same size. That is, unless it can live outside in the boneyard 'til we find a way to reuse it.

Otto, a friend, and I raised two weaner pigs years ago. I went to the local grocery store and asked for any produce they threw away. The store guy was so generous he let me *take* his garbage cans. I would give the discarded produce to the pigs, then clean and return his cans. He liked it, I liked it, and the pigs liked it.

A man I know has been practicing Freeganism in the town where he lives by giving the food he finds to people who are cash-poor. The food is still fresh, safe food: a box of cereal that has a box-cutter slash on it, a dozen eggs with one cracked, cheese at its "expiration" date. So many things are thrown out. Did you ever wonder how your bakery could have fresh bread daily? They often throw out yesterday's bread. So much waste. And it's even worse in these times, when more and more people have to turn to food banks for help.

Free Market

Beyond Freeganism, another idea that I am enamored with is Free Markets. Sometimes they're called Freemeets. You take your good, usable, no-longer-needed items and give them away. Unlike a flea market, no money changes hands. Reuse trumps recycling every time, since it keeps the product in circulation without the need for more manufacturing inputs.

I could really use a Free Market in my area. I have some good stuff that, although we're not using it anymore, I am unwilling to send to the dump. And donating to area thrift stores is out—most of them can be picky about what they take, especially anything electric or electronic. To pack up stuff for the thrift store, only to have it refused, is a waste. I don't

Freecycling

I've been a dumpster diver for about 30 years. Most recently, I've been diving in a college town, where waste is so rampant it's almost criminal. This problem is mostly due to college students leaving things behind when they have to move out of the dormitories and apartments. I have found everything from a bicycle to a barbecue grill, from new clothing with the tags still on to barely scuffed work boots.

Now I live in an apartment in Sacramento, and I am also finding useful goods in the dumpster here—usually after somebody has moved out. Recently, I found a big bag of clothing and a daypack with some very old coins tucked inside a pocket. The things I don't need, I pass on, usually to one of two thrift stores within walking distance of my apartment. Both of these stores raise money for nonprofits, one helping to feed and house the homeless and the other helping to find homes for abandoned pets.

But, by far, my favorite way to either pass on or find things I want is via Freecycle (www.freecycle.org), which connects people offering stuff with people wanting stuff, using regional e-mail listservers. There are nearly 5,000 regional groups with more than 6.5 million members across the globe.

In fact, I have a "wanted" listing out right now—I'm hoping to find an Xtracycle kit to convert my bike to a cargo bike. It's true that one person's trash can indeed be another's treasure. Like Freeganing and Freemeets, Freecycle keeps goods in circulation, giving new life to old stuff and keeping it out of the landfills.

—Michael Welch

want to advertise items in the newspaper or on Craigslist because whoever was interested in them would likely have to drive a long way just to see them. If the items weren't to their liking, what a waste of time and gas that would be. And I will never have a yard sale at my house. It is just too far in the boondocks. Plus, I don't want additional traffic on our single-lane dirt road. When I meet another vehicle on our road that I don't recognize, I want to brandish a front bumper sticker that says, "*You* Back Up: I Live Here."

Freedback

I have all sorts of items I would gladly give away. Now I just hang onto them, asking my friends if they need an electric printing desk calculator/all-in-one color fax machine/assorted office chairs/box of old radio tubes (I'd better ask Bob-O about that last one). This is a hit-or-miss proposition at best. But the Free Market—that would be the ticket.

I've been talking to my friends about this idea and have gotten good feedback. There would be several issues to address. You would need volunteers to help set it up and advertise. After it was started, word-of-mouth advertising would be enough. People could not bring trash or unusable items, or abandon unadopted items that no one wanted. Someone would have to staff each table at all times. Depending on where you got permission to hold the Free Market, there might be insurance and fees that would apply.

Although this flies in the face of the whole "free" part of the idea, one friend suggested charging a deposit to help ensure folks leave with their leftovers. I like that idea. It's sad to think you'd have to enforce what should be personal responsibility, but I can see where it would be a good precaution.

Freemeet

Think of all the still-good, usable things that could be saved from the landfills. Free "finders" could save a lot of money. And "givers" would get the gratification of seeing their old items get a new life. Plus, they just get to feel better about themselves and the planet. Let's have a big dose of Greed-B-Gone. We need to stop being a throwaway society. We are wasteful and that has to change.

The Free Market could extend to consumables, too: How about during garden season when you can easily have an overabundance of vegetables or fruit? We may be "too country" here to have dumpsters, but we do have gardens. This is the kind of place where you hear that old saw about only having to lock your car doors in August. Why? Because if you don't, you'll come back to shopping bags full of squash in your backseat. (This happens to be true.)

Beyond the material benefits, when I imagine a Freemeet, I see a place where people connect with one another. You hear why a person needs your item; they listen to why you don't. Freemeets would facilitate people talking to each other, face to face. The fact that everything is free pretty much guarantees satisfaction. I imagine a happy place, a productive place, on several levels.

I guess it all comes down to how much am I willing to do to make sure my usable castoffs get another home. That all sounds very noble, but I do have an ulterior motive. If I find homes for all my stuff, I'll be able to shop for other stuff at the Free Market. You never know what I might find.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is addicted to playing www.freerice.com at her off-grid home in northernmost California.

Michael Welch (michael.welch@homepower.com) continues to dumpster dive and distribute found goods in Sacramento, California, but looks forward to equally bounteous dumpsters when he returns home to Humboldt County.

RE happenings

ARIZONA
Sep. 12–13, '09. Flagstaff. Northern AZ Sustainable Living Fair. Exhibits, lectures & workshops. RE, EVs, green building, kids' events & more. Info: info@nazsla.org • www.nazsla.org

CALIFORNIA
Jul. 14–16, '09. San Francisco. Intersolar North America. Solar trade exhibit & conf. Market developments & trends, government policies & technology & products. Info: www.intersolar.us

Aug. 8–9, '09. Hopland, CA. SolFest. RE booths, workshops & kids' activities. Food & entertainment. Info: www.solfest.org

Oct. 27–29, '09. Anaheim, CA. Solar Power 2009. Conference & expo. Info: SEIA • 202-296-1688 • www.solarpowerconference.com

Arcata, CA. Workshops & presentations on RE & sustainable living. Info: Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO
Aug. 29–30, '09. Crestone, CO. Crestone Energy & Sustainability Fair. Info: 719-256-5572 • chokecherry@fairpoint.net

Sept. 19–20, '09. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative vehicles & more. Info: kellie@sustainablelivingfair.org • www.sustainablelivingfair.org

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water & more. Info: Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA
Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

ILLINOIS
Aug. 8–9, '09. Oregon, IL. IL RE & Sustainable Lifestyle Fair. RE booths, workshops, tours & kids' activities. Food & entertainment. Info: www.illinoisrenew.org

IOWA
Sep. 12–13, '09. Cedar Falls, IA. I-Renew Energy Expo. Workshops, exhibits, food, entertainment. Info: www.irenew.org

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS
Hudson, MA. Workshops: PV, wind & solar thermal. Intro to advanced. Info: The Alternative Energy Store • 877-878-4060 • workshops@altestore.com • http://workshops.altenergystore.com

MICHIGAN
Jun. 26–28, '09. Onekama, MI. Michigan Energy Fair. Workshops, exhibits & speakers on solar, wind, alt. transportation & building. Info: www.glrea.org

West Branch, MI. Intro to solar, wind & hydro. 1st Fri. each month. Residential system design & layout. Info: 989-685-3527 • gotter@m33access. com • www.loghavenbbb.com

MISSOURI
Gerald, MO. Workshops on energy efficiency, PV, wind, solar heating & more. Info: Evergreen Institute • info@evergreeninstitute.org • www.evergreeninstitute.org

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Info: Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA
Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV, more. Info: Sage Mt. Center • 406-494-9875 • www.sagemountain.org

NEW HAMPSHIRE
Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO
Sep. 26–27, '09. Albuquerque. Solar Fiesta. RE & EE exhibits & workshops. Info: (see below)

Six NMSEA regional chapters meet monthly, with speakers. Info: NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NORTH CAROLINA
Aug. 21–23, '09. Fletcher, NC. Southern Energy & Environment Expo. RE displays, exhibits & presentations. Info: www.seeexpo.com

Saxapahaw, NC. Solar-powered home workshop. Info: Solar Village Inst. • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OHIO
Cleveland, Cincinnati, etc. Workshops & RE events throughout the state. Info: www.greenenergyohio.org

OREGON
Jul. 20–24, '09. John Day, OR. Pre-SolWest workshops. Cob building, NABCEP prep. & SHW installation. Info: (see EORenew below)

Jul. 24–26, '09. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA
Jun. 13–14, '09. Dallas, PA. NE Penn. Energy Solutions Expo. Exhibits, vendors & presentations on solar, wind, biofuels & more. Info: 570-282-8732 ext. 4 • sue@pnercd.org • www.pnesolutions.org

Sep. 18–20, '09. Kempton, PA. Penn. RE & Sustainable Living Festival. RE, natural building & sustainable ag; workshops, speakers, exhibits. Info: www.paenergyfest.com

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

RHODE ISLAND
Jun. 6–7, '09. Coventry, RI. RI Sustainable Living Festival & Clean Energy Expo. RE, efficiency & building; workshops, music & exhibitors. Info: www.livingfest.org

TENNESSEE
Summertown, TN. Workshops on PV, alternative fuels, green building & more. Info: The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS
Sep. 25–27, '09. Fredericksburg, TX. RE Roundup & Green Living Fair. Exhibits, speakers & workshops on RE, green building, green ag & EE. Info: www.theroundup.org

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. Info: EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group, quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

VERMONT
Jul. 10–12, '09. Tinmouth, VT. SolarFest. RE workshops, speakers, music, theatre, food & more. Info: www.solarfest.org

WASHINGTON STATE
Jul. 18, '09. Shoreline, WA. Shoreline Sustainable Living & RE Fair. Exhibits & speakers. Info: www.shorelinesolar.org

Guemes Island, WA. SEI '09 workshops. Oct. 19–24: Advanced PV; Oct. 26–31: EV Conversion. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian@solarenergy.org

WISCONSIN
Jun. 19–21, '09. Custer, WI. The Energy Fair (a.k.a. MREF). Exhibits & workshops on solar, wind, green building, transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '09 workshops: Basic, int. & adv. RE; PV site auditor certification test; veg. oil & biodiesel; solar water & space heating; masonry heaters; wind site assessor training & more. Info: 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha '09 workshops: Intro to Solar Water & Space Heating Systems; Installing a Solar Water Heating System; Living Sustainably & more. Info: 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

INTERNATIONAL

CANADA
Downsview, ON. Workshops on RE, PV, wind, SHW, green building, efficient heating & more. Info: www.kortright.org

GERMANY
Sep. 21–25, '09. Hamburg. European PV Conference & Exhibition. Latest developments in science & industry. Info: www.photovoltaic-conference.com

NICARAGUA
Jul. 6–16, '09. Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Info: 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

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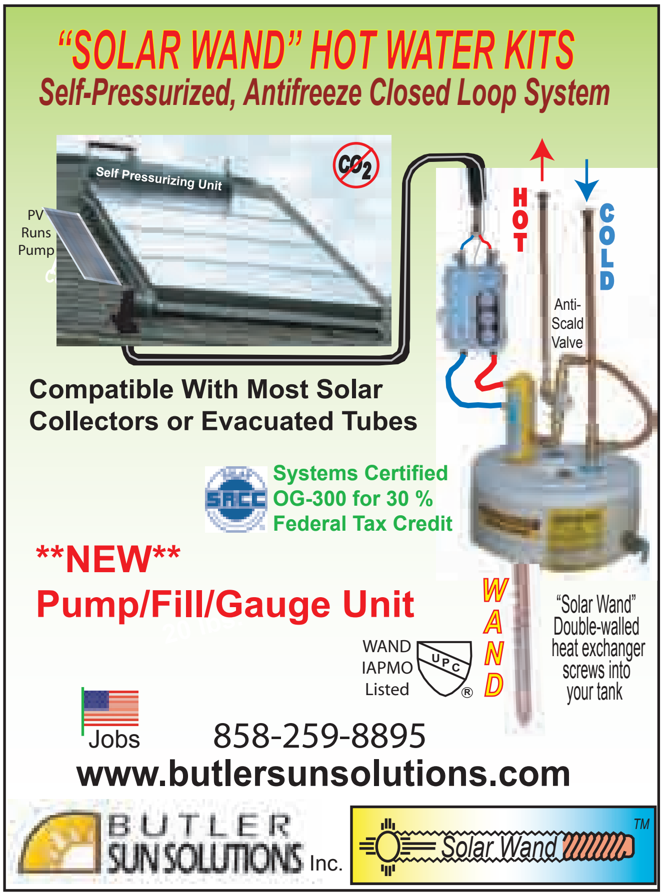
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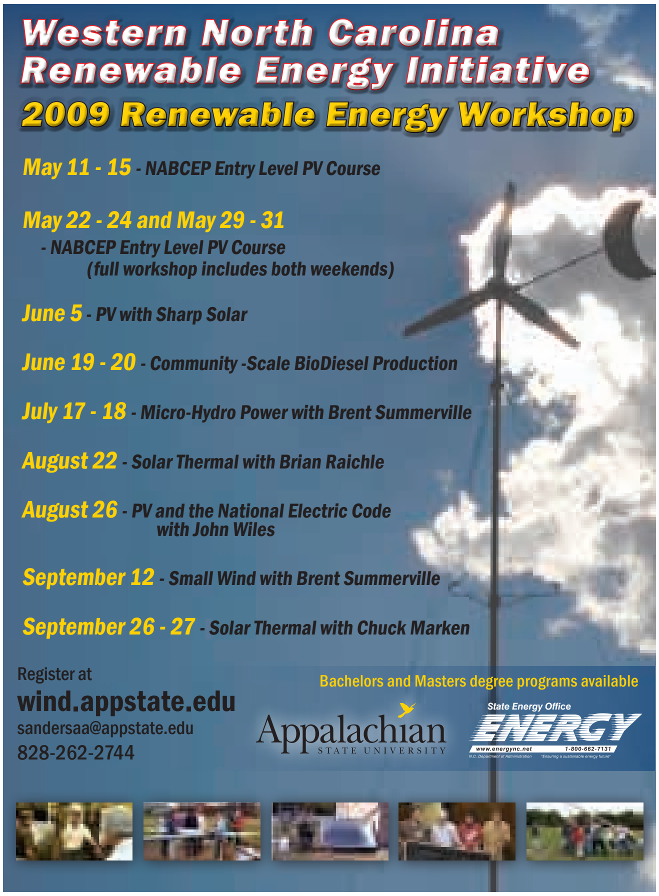
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August 26 - PV and the National Electric Code with John Wiles
September 12 - Small Wind with Brent Summerville
September 26 - 27 - Solar Thermal with Chuck Marken
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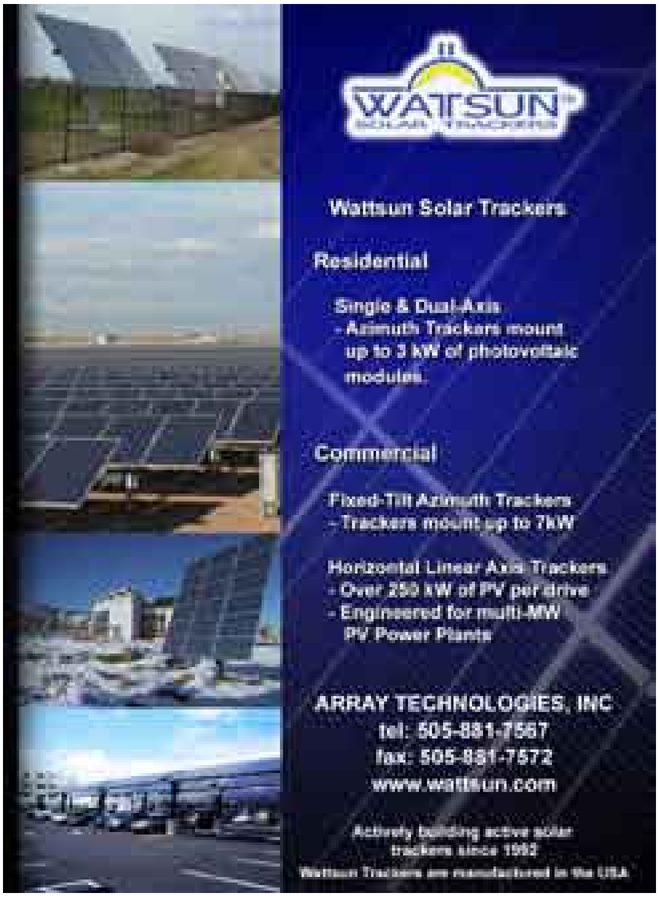
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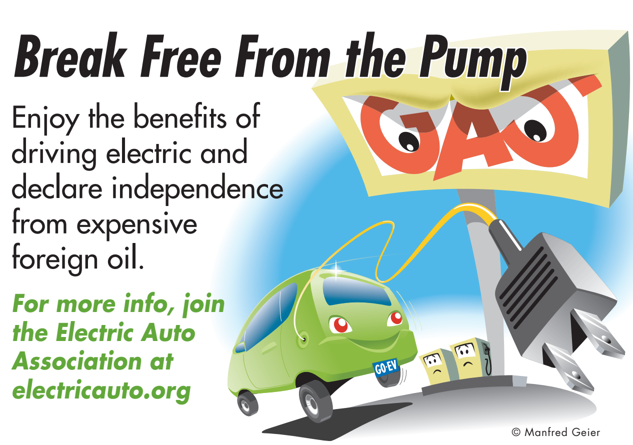
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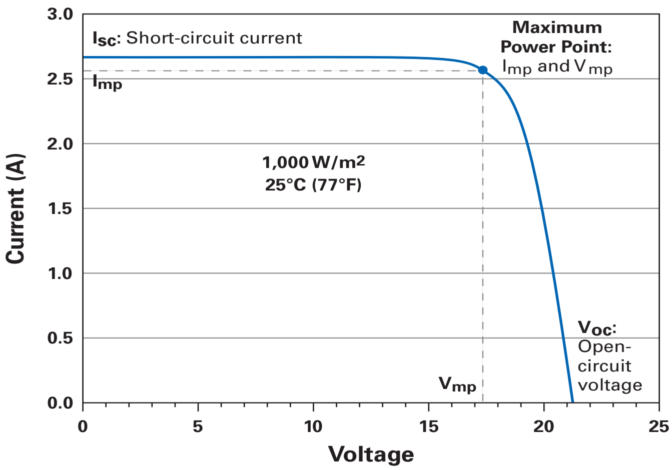
Current, Voltage & Maximum Power Point

PV modules operate between two extremes—from no load and no voltage at short-circuit current (Isc) to infinite load with no current at open-circuit voltage (Voc). The actual power output (P) is a product of current (I) and voltage (V): **P = I x V.**

The current–voltage (a.k.a. IV) curve is a graphic representation of a PV module's electrical output. It depicts the module's possible operating points at standard test conditions (STC), and the relationship between current and voltage. At either the Isc or Voc, no power is available. The point on the curve that reflects the highest power output is where the product of current and voltage is greatest—the maximum power point (MPP).

Example Module IV Curve at STC



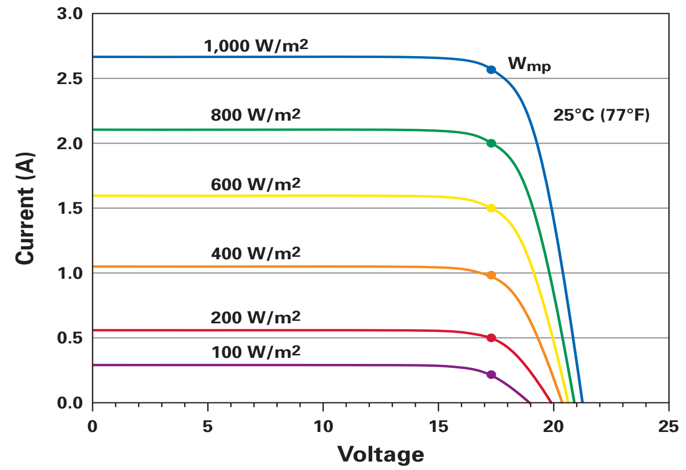
In this example, the maximum power point occurs at approximately 17 V and 2.5 A to produce 42.5 W (17 V x 2.5 A). Every other point produces less than 42.5 W.

Unfortunately, a module does not just naturally reach its MPP and stay there. Three major factors affect how modules operate—sunlight intensity, temperature, and electrical loads. As sun intensity and temperature vary over the course of the day, the IV curve and MPP also fluctuate. And while we have little control over sunlight and temperature, we can control the loads placed on a module or array, since they ultimately determine the operating point on the IV curve.

For example, being connected to a 12 V nominal battery will cause a module to operate between 12 V and 15 V during the charging process. Even if environmental conditions are sufficient to produce more voltage, the battery forces the module to operate at a voltage lower than its MPP—effectively offering less power than its potential.

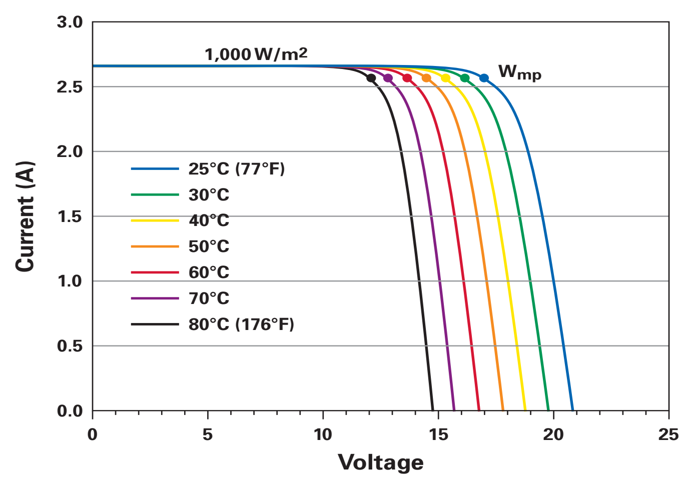
Maximum power point tracking (MPPT) circuits—like those found in grid-tie inverters and many charge controllers—respond to

Effect of Insolation on Module Performance



Less sunlight creates a curve that is much shorter, since current is reduced. As a result, available power is reduced.

Effect of Cell Temperature on Module Performance



Higher cell-operating temperatures take a bite out of the perfect IV curve, reducing the operating voltage and available power.

the variations in PV operating conditions to maximize power, adjusting the load's resistance so that the electrical system caters to the PV module/array's optimal operating point. For battery charging, an MPPT charge controller manages the "extra" voltage above battery voltage intelligently to maximize power. Utility-interactive batteryless MPPT inverters dynamically adjust the resistance applied to the PV array to match the maximum power voltage and current.

—Erika Weliczko, *Home Power* Technical Editor